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AN EVALUATION OF TECHNIQUES FOR THE MEASUREMENT OF LOW CONCENTRATIONS OF TRACE GASES IN THE ATMOSPHERE

by

Clifford E. Decker and James R. Smith
Research Triangle Institute
Research Triangle Park, North Carolina

and

Gordon C. Ortman
National Air Pollution Control Administration
Durham, North Carolina

Contract No. CPA 22-69-109

FINAL REPORT

February 1970

Prepared for

National Air Pollution Control Administration
411 West Chapel Hill Street
Durham, North Carolina

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A research experiment was conducted aboard the S.S. ADVANCE II from Wilmington, North Carolina to the vicinity of the equator and return. Ozone, total oxidant, carbon monoxide; and methane concentrations were measured and comparative evaluation of the chemiluminescent and coulometric techniques for measuring ozone and oxidant of low atmospheric concentrations was conducted. The results suggest that both the chemiluminescent and coulometric measurement techniques will provide useful data at the low concentrations found in a relatively unpolluted marine environment. The chemiluminescent meter is more reliable than the coulometric meter under the conditions encountered. Although a precise quantitive estimate of the accuracy of the two techniques cannot be made on the basis of the data obtained, the evidence indicates that the chemiluminescent technique is significantly more accurate.

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FOREWORD

This report was prepared by members of the Engineering and Environmental Sciences Division (EESD) of the Research Triangle Institute (RTI), Research Triangle Park, North Carolina under Contract No. CPA 22-69-109.

The work was sponsored by the Division of Chemical & Physical Research and Development, National Air Pollution Control Administration (NAPCA) under the direction of Dr. A. P. Altshuller.

The Project Director was Mr. James R. Smith. Messrs. Clifford E. Decker and Ronald B. Strong were primarily responsible for the measurements aboard the S. S. ADVANCE II. Chemical analyses were conducted by Messrs. Clifford E. Decker, RTI, and Gordon Ortman, NAPCA.

Special acknowledgement is due Captain Arthur W. Jordan and the crew of the S. S. ADVANCE II, and the students from the Cape Fear Technical Institute, Wilmington, North Carolina for the outstanding cooperation and assistance throughout the cruise.

ABSTRACT

During June and July 1969, RTI conducted a research cruise aboard the S. S. ADVANCE II from Wilmington, North Carolina to the vicinity of the equator and return. Ozone, total oxidant, carbon monoxide, and methane concentrations were measured and comparative evaluation of the chemiluminescent and coulometric techniques for measuring ozone and oxidant at low atmospheric concentrations was conducted. The results suggest that both the chemiluminescent and coulometric measurement techniques will provide useful data at the low concentrations found in a relatively unpolluted marine environment. The chemiluminescent meter is more reliable than the coulometric meter under the conditions encountered. Although a precise quantitative estimate of the accuracy of the two techniques cannot be made on the basis of the data obtained, the evidence indicates that the chemiluminescent technique is significantly more accurate. As indicated by the calibration data, and a comparison of the ambient measurements at low concentrations, errors of at least 100% might be expected with the coulometric meter. The interference problem is greater with the coulometric meter.

The following mean concentrations were observed:

Ozone - 0.5 pphm
Oxidant - 0.9 pphm
CO - 0.18 ppm
CH_4 - 1.36 ppm

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SECTION I

INTRODUCTION

Inherent in the concept of air quality is a knowledge of the concentration and behavior of those constituents used as a measure of air quality. Important among these constituents are ozone and total oxidant. The objective of this study was to compare established instrumental techniques for measuring atmospheric oxidants at the low atmospheric concentrations, and to obtain background measurements of O_3, O_x, CO, and CH_4 in a marine environment.

The three techniques most commonly used for measuring oxidant concentrations in the atmosphere are: (1) colorimetric, (2) coulometric, and (3) chemiluminescent. The colorimetric and coulometric techniques are considered "total oxidant" measurements. They are subject to interference by reducing agents such as SO_2. The SO_2 problem, however, can be eliminated by use of a CrO_3 scrubber which oxidizes SO_2 to SO_3. The chemiluminescent technique has proven to be, within acceptable limits, specific for ozone--which usually is the principal oxidant during daylight hours.

Recent work done by the Research Triangle Institute, under Contract No. PH 22-68-30, in urban environments has served to emphasize the complexity of the problem of interpretation of total oxidant measurements. This study indicated that the reproducibility (or repeatability) of the chemiluminescent technique generally is quite good even in an urban (i.e., polluted) atmosphere. Although exhaustive tests have not been conducted, this does not appear to be true in the case of the

colorimetric and coulometric techniques. The results obtained not only raised serious questions concerning the reliability of the sampling techniques, but also the nature and behavior of total oxidants--particularly in a polluted atmosphere. Prior to the study covered by this report, extensive tests had not been conducted in an "unpolluted" atmosphere; hence, it was not known whether the instruments would behave in a comparable manner.

During the period of June and July RTI conducted a research experiment aboard the S. S. ADVANCE II. The cruise track extended from Wilmington, North Carolina to the vicinity of the equator and return. This cruise provided an opportunity to evaluate the chemiluminescent and coulometric measurement techniques at low concentrations of atmospheric oxidant. The results are presented in this report. A very significant by-product of the study was the collection of a valuable set of measurements of background concentrations of total oxidant, ozone, carbon monoxide, and methane in a marine environment.

SECTION II

RESEARCH OBJECTIVES

The primary purpose of this study was to conduct a comparative evaluation of the principal techniques for measuring oxidants at low atmospheric concentrations, and, if possible, to establish the oxidant-ozone relationship as found in a marine environment. The secondary objective was to observe and analyze the concentration of ozone (O_3), total oxidant (O_x), carbon monoxide (CO), and methane (CH_4) in this type of environment.

SECTION III

MEASUREMENT TECHNIQUES

Crucial to the interpretation of the data obtained in this study is an understanding of the instrumentation used. The chemiluminescent technique used to monitor ozone was developed by Regener[1]. The principle of operation is based upon the reaction of ozone with certain organic dyes to cause an emission of a minute amount of light. The amount of light emitted and viewed by a photomultiplier tube is proportional to the ozone concentration. The chemiluminescent ozone meter used in this study has a dynamic, internal calibration system so that alternate ambient measurement and calibration signals are displayed on a strip-chart recorder in a ten-minute cycle. In addition, the electronic stability of the system and the recorder is monitored during each ten-minute cycle. No compound yet found in polluted air, at usually experienced concentrations, except PAN, is known to interfere with the chemiluminescent measurement of ozone. The chemiluminescent technique is extremely sensitive, specific, and permits extended monitoring of ozone with concurrent calibration signals for accurate comparison of the data from beginning to end of an experimental period.

A coulometric total oxidant meter (Mast) was used during this study to measure total oxidant. The principle of operation is based upon the reaction of oxidants (including ozone) in the sampled air with iodide ions (in neutral-buffered KI solution) to produce iodine. There is a small potential across the electrodes in the sensing

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element, and when iodine is produced a current is generated which is proportional to the concentration of oxidant. This type of instrument responds to any substance which oxidizes iodide to iodine; however, the rate of reaction for ozone is much more rapid than for other oxidants.

The coulometric total oxidant meter is subject to interference by SO_2 and possibly other unknown reducing agents. For example, iodine formed by ozone in neutral buffered KI solutions is reduced rapidly to iodide by SO_2. The reaction is stoichiometric and results in one molecule of iodine being reduced to iodide for each molecule of SO_2, which is present in the air sample and reacts with the iodine. Other reducing agents in the atmosphere most likely behave in a similar manner; but, because their nature and concentrations are unknown, their interference with the coulometric oxidant meter is quantitatively unknown. One procedure for eliminating this interference is to pass the incoming air stream through a CrO_3 "scrubber" which oxidizes the SO_2 to SO_3. The SO_3 does not react with iodine; however, the CrO_3 scrubber will oxidize some of the NO in the air stream to NO_2, which produces a positive interference. In this study two coulometric instruments were used--one with a CrO_3 scrubber (#2) and one without (#1)—so that a comparision of results with and without SO_2 interference might be studied.

The neutral buffered KI technique for measuring total oxidant, as described in the "Selected Methods Manual"[2], was used as a referee for calibration and periodically as a sampling technique for ambient conditions. The sampling train and technique are

described in Section IV. This technique, when used to sample ambient air suffers from the same interference problems as does the coulometric technique. One-hour integrated samples were measured periodically by the neutral buffered KI technique to compare with measurements by the chemiluminescent and coulometric instruments.

Facilities for in situ analyses of carbon monoxide (CO) and methane (CH_4) were not available. One-liter evacuated stainless steel cylinders were used to collect atmospheric samples at 6-hourly intervals. These samples were returned to NAPCA and were subsequently analyzed by Mr. G. C. Ortman using the gas chromatographic technique described below.

Standard gases were purchased from Scott Research Laboratories Inc., Plumsteadville, Penn. These gases, contained in 1A cylinders (44 liter volume), were analyzed by Scott on a 40 meter I.R. analyzer and designated to contain the following concentration:

	CO ppm	CH_4 ppm
CYLINDER #1	9.22	8.44
CYLINDER #2	4.98	5.07
CYLINDER #3	1.04	1.04
ZERO GAS	<.1	<.1 Total H_c as CH_4

The above mixtures were made up by Scott using "zero" air as a diluent. The zero gas was prepared by passing commercial cylinder air through a heated catalyst bed followed by driers and activated carbon.

The Scott gases also were checked against standard gases prepared in NAPCA laboratories, which were prepared with equal concentrations of CO and CH_4 to levels of 1.00, 5.00, and 10.00, ppm using Scott

"Zero Air" as a diluent according to the procedure described by Stevens, et al.[3] Briefly, the procedure consists of using three cylinders, size 1A standard 44 liters, having a volume known to be ± 10 ml, and pipettes whose volumes were determined gravimetrically by filling with mercury. Known volumes of pure CO and CH_4 were injected into the three cylinders which had been evacuated and flushed several times with "Zero Air" and finally evacuated to less than one torr. Finally the three cylinders were pressurized to the gauge pressure calculated to give the desired 1, 5, and 10 ppm concentration. Comparable checks on the gases prepared by Scott and those prepared by NAPCA showed excellent agreement. In the series of analysis performed, it was found that the "Zero" gas contained 0.00 ppm CH_4 and 0.055 CO. The trace of CO in the "Zero" gas was taken into account in preparation of the NAPCA standards and in zeroing the analyzer. Also the corrections were used in charging the sample cylinders to two (2) atmospheres as discussed below.

The procedure followed in the analysis of the grab samples collected during the cruise was to pressurize (using a mercury manometer) the bottles with zero gas to exactly two (2) atmospheres. The MSA gas chromatograph was calibrated by charging an evacuated bottle with the 1.00 ppm standard to one atmosphere and then further charging the bottle to two atmospheres with the zero gas. The span controls on the amplifier for carbon monoxide and methane, and the millivolt setting on the recorder, were adjusted so that the above prepared standard gas gave a 50% reading. This reading was therefore equivalent to 2.00 ppm CH_4 and 2.0 ppm CO at full scale. It was anticipated

that concentrations observed during the cruise would not exceed thse values, and as it turned out this assumption was correct. Consequently, all analyses were performed on this scale and new standard bottles as described above were frequently made up and the instrument calibration rechecked. Each sample was analyzed at least twice and the maximum deviation between any two analyses of the same sample was $\pm$ 1 chart division, or $\pm$ .02 ppm. A 20 cc sample loop was used in the MSA system. This was flushed at a rate of 30 cc per minute for 5 minutes followed by injections using the pressurize cylinder in the flow control system.

It is believed, based on repeatability of the readings both for samples and for the standard, as well as statistical analysis of possible analytical errors, that the values reported both for the CH_4 and CO were within 0.02 ppm of the absolute concentration.

SECTION IV

CALIBRATION PROCEDURES

The chemiluminescent and coulometric instruments used during the measurement program were calibrated by having each instrument sample simultaneously from a common manifold. The neutral buffered KI technique was used as the standard, or referee method for determining ozone concentration in the manifold air stream. Previous tests[4], using the ozone generator system shown in Figure 1, have demonstrated that the ozone concentration remained constant in all parts of the manifold during the calibration experiments. Calibrations of the instruments were performed four times during the cruise using the following procedure.

A. Apparatus

(1) Absorbers - All glass midget impingers with ball and socket joints.

(2) Air-metering device - A critical orifice capable of delivering 1 ℓ/min at 20 in. Hg vacuum. Calibrated by wet test meter.

(3) Vacuum source - Gast pump or its equivalent.

(4) Spectronic 20 spectrophotometer.

(5) Manifold - Glass manifold, 1" O.D. Pyrex glass, 2 feet long with sampling ports.

(6) Clean air supply - Ambient air was passed through a MnO_2 and charcoal trap at a rate 1 liter per minute.

(7) Ozone generator - UV lamp (Pen-Ray Model 11SC-1B)

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B. Reagents

Neutral, buffered KI, 1%. Procedure as specified in the "Selected Methods for Measurement of Air Pollutants"[2].

C. Design of Calibration System

The manifold was set up as shown in Figure 1, with a flow rate of about 1 ℓ/min. The positions in Figure 1 labeled Chem. #1, #2, and #3, refer to the three sampling lines of the chemiluminescent instrument. Line #3 was placed at the end of the manifold because during a certain portion of the chemiluminescent meter 10-minute cycle, ozone is ejected from this line. In this end position the ejected ozone did not affect the other instruments.

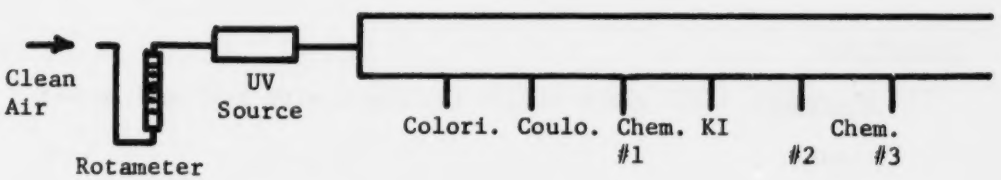

Figure 1. Diagram of Calibration Train and Manifold.

The sampling train (Figure 2) for the KI method consisted of two series-connected midget impingers, a critical orifice, and a pump.

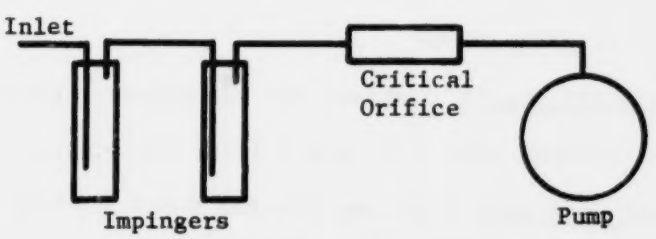

Figure 2. Diagram of Train for Ozone Determination By KI Technique.

All connectors and inlet tubing were of glass or Teflon. Each impinger was labeled so that its position remained the same throughout the studies. The impingers, inlet lines, and manifold were cleaned thoroughly before each calibration run.

D. Sampling Procedure for Determining Oxidants by the KI Method

(1) Prepare a solution of 1% neutral KI as prescribed in "Selected Methods Manual"[2].

(2) Prepare a calibration curve using a standard iodine solution--which is standardized using a KIO_3 primary standard and diluted to appropriate volumes with neutral buffered absorbing solution.

(3) Pipette 10 ml of absorbing reagent into each impinger and assemble the train (Figure 2). Protect the impinger from exposure to sunlight with suitable wrappings.

(4) Connect the train to the manifold and sample at 1 ℓ/min for no more than 15 minutes.

(5) Transfer the solution to a 1" absorbance cell and measure the absorbance at 335 mμ in a Spectronic 20. Obtain the number of μl O_3/ml from a previously prepared calibration working curve where absorbance is plotted against concentration.

(6) Determine the concentration of ozone in pphm using the following formula:

$$\text{pphm } O_3 = \frac{\mu l\ O_3/ml \times ml \text{ solution} \times 10^2}{\text{Volume of gas sampled (liters)}}$$

It is necessary that the working curve be expressed in ozone concentration units (μl/ml) compatible with the volume units of the gas sampled (i.e., both volumes determined at the same barometric pressure).

E. Calibration Results

The maximum output for the UV calibration source, at one liter per minute flow rate, was 2.05 pphm. This maximum output remained very stable throughout the cruise; hence, it was used as the principal calibration point. Further, the concentrations usually found in the ambient atmosphere ranged from near zero to about 2 pphm. During each calibration check a run was made where zero ozone was supplied to the manifold to determine "oxidant background" for each instrument.

The calibration results are shown in Table I and the corresponding correction equations are given in Table II. The calibration factor for the UV calibration lamp on the chemiluminescent (Regener) instrument was determined to be 12.2 and remained constant during all calibration experiments. The correction factors for both coulometric meters (with and without the CrO_3) varied by about a factor of two (2) during the period of the cruise.

Table I

CALIBRATION DATA FOR CHEMILUMINESCENT
AND COULOMETRIC INSTRUMENTS (IN PPHM OZONE)

Date	Hour (GMT)	KI	$O_3(R)$	$O_x(M_1)$	$O_x(M_2)$
6/8/69	1800	0.0	0.0	0.0	0.0
		2.05	2.05	2.5	1.7
6/21/69	2300	0.0	0.0	0.0	0.0
		2.05	2.05	1.25	1.0
7/6/69	1400	0.0	0.0	0.4	0.0
		2.05	2.05	2.5	1.1
7/16/69	1400	0.0	0.0	0.5	0.2
		2.05	2.05	1.9	1.5

$O_3(R)$ - Chemiluminescent (Regener)

$O_x(M_1)$ - Coulometric without scrubber (Mast)

$O_x(M_2)$ - Coulometric with CrO_3 scrubber (Mast)

Table II

OXIDANT CORRECTION EQUATIONS

Date	Hour (GMT)	$O_3(R)$	$O_x(M_1)$	$O_x(M_2)$
6/8/69	1800	N.C.	$O_x = (M_1)(0.82)$	$O_x = (M_2)(1.21)$
6/21/69	2300	N.C.	$O_x = (M_1)(1.64)$	$O_x = (M_2)(2.05)$
7/6/69	1400	N.C.	$O_x = (M_1 - 0.4)(0.82)$	$O_x = (M_2)(1.86)$
7/16/69	1400	N.C.	$O_x = (M_1 - 0.5)(1.07)$	$O_x = (M_2 - 0.2)(1.37)$

$O_3(R)$ - Chemiluminescent (Regener)

$O_x(M_1)$ - Coulometric without scrubber (Mast)

$O_x(M_2)$ - Coulometric with CrO_3 scrubber (Mast)

N.C. - No correction. Values obtained using Regener UV lamp calibration factor of 12.2 are equivalent to neutral KI values.

SECTION V

FIELD MEASUREMENT PROGRAM

The track for the cruise of the ADVANCE II, shown in Figure 3, extended from Wilmington, North Carolina to the equator and return. The cruise provided the opportunity to observe the concentrations of trace gases in the marine atmosphere over a wide geographical range. The atmospheric environment covered is relatively unpolluted, hence the results obtained should be reasonably representative of the geophysical background for this region.

A number of other experiments were conducted aboard the ADVANCE II during the cruise; however, only those data considered pertinent to the sampling of atmospheric trace gases are presented in this report.

The following trace gases were measured routinely throughout the duration of the cruise: (1) ozone (chemiluminescent ozone meter), (2) total oxidant (Mast ozone meter), (3) sulfur dioxide (West & Gaeke Method), (4) nitrogen dioxide, nitric oxide (Saltzman method), and (5) methane and carbon monoxide (grab samples - subsequent gas chromatographic analyses by NAPCA). Weather and sea observations included temperature, humidity, solar radiation, wind speed and direction, visibility, sea surface temperature and salinity, and sea state.

Sample air was transported to the ship's laboratory via 1" O.D. TFE Teflon tubing and connected to a glass manifold equipped with sampling ports for all instruments. The sampling inlet was located above the flying bridge at approximately 15 meters above sea level,

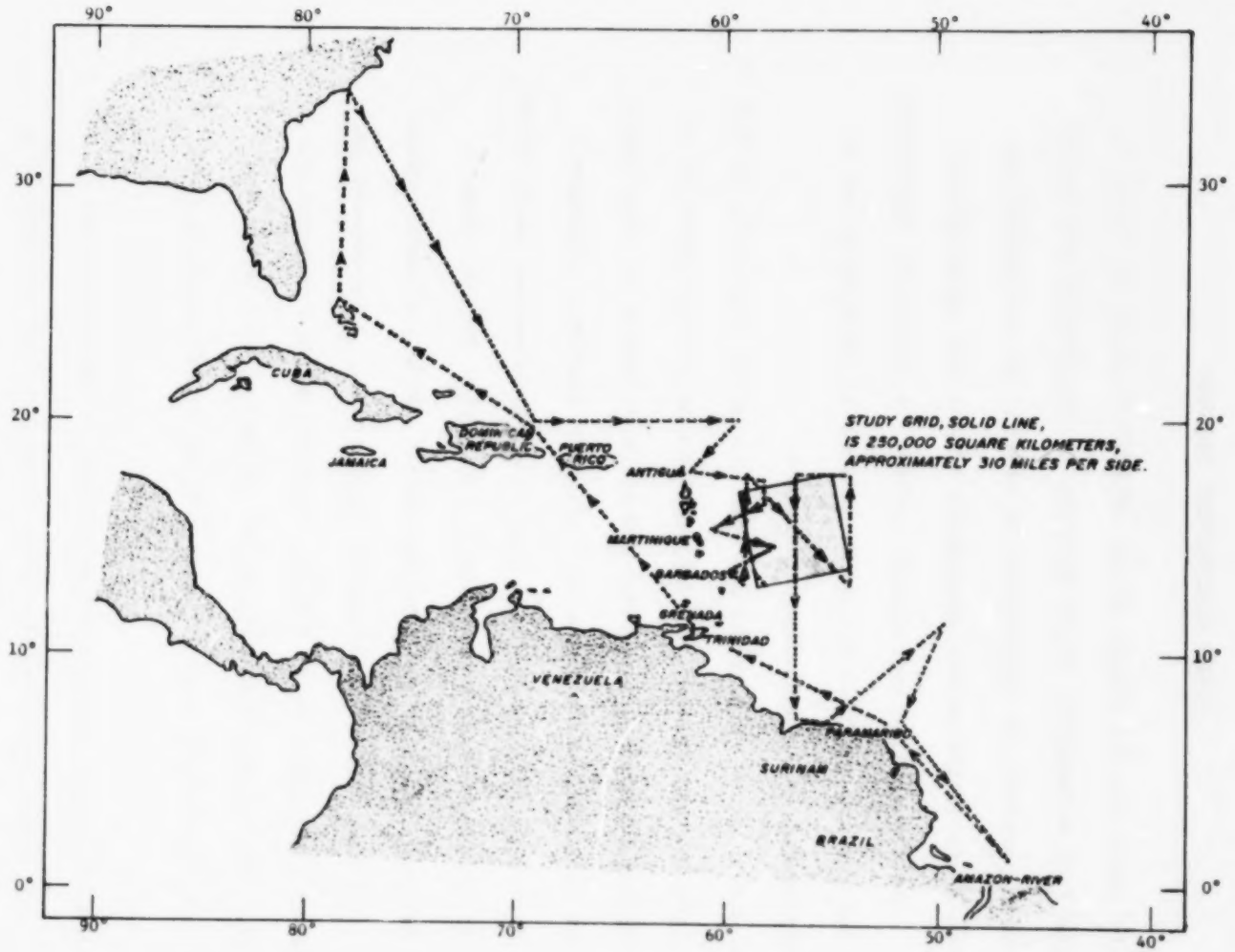

Figure 3. Cruise Track, S. S. ADVANCE II
Period - 8 June through 21 July 1968

and was protected by a glass cone which prevented water (rain and ocean spray) from entering the sampling line. Sample air was aspirated through the sampling line via a blower at a rate of 1 cubic foot per minute. This rate is consistent with data which have been established at RTI to minimize turbulence and destruction of ozone in the sampling line. To determine whether or not oxidant was being destroyed in the Teflon sampling line a Mast ozone meter was operated periodically near the inlet. The data indicated that no detectable amount of oxidant was being destroyed in the sampling line.

Two Mast ozone meters (one with and one without a chromium trioxide scrubber) and a Regener chemiluminescent ozone meter were attached to the sampling manifold via Teflon tubing and ball and socket joints. Inlets for the 2 hour integrated sampling systems for NO, NO_2, and SO_2 also were connected to the manifold via Teflon tubing.

Evacuated grab sampling containers were used to collect samples for CO and CH_4.

The following sampling schedule was maintained throughout the duration of the cruise:

1) Chemiluminescent ozone measurements at 10-minute intervals.
2) Continuous total oxidant measurements using the coulometric technique (Mast ozone meter). Two meters were used; i.e. one with and one without a CrO_3 scrubber.
3) Atmospheric grab samples at 6-hour intervals.
4) Periodic calibration of ozone and oxidant instruments using the neutral KI technique.

5) Two-hour integrated measurements for NO, NO_2, and SO_2.

6) Relative wind speed and direction, solar radiation, air temperature at 5 and 20 meters, and sea surface temperature were monitored continuously and recorded on a strip chart sequential recorder.

7) Three-hourly weather and sea state observations.

8) Periodic radiosonde soundings were made to obtain a vertical profile of temperature, humidity, and pressure.

Tabulated data covering items (1) through (4) are included in Appendix A.

SECTION VI

DATA REDUCTION AND ANALYSIS

All data were recorded either automatically on analog charts or manually on log sheets. Significant data have been extracted from these records and entered on computer punch cards. Punch card entries are either in output voltages or parametric values, depending upon the recording technique used. Computer programs were prepared which applied the necessary transfer and calibration equations to obtain corrected values for each measurement. A computer printout of the tabulated data was obtained from these values. The computer printout tabulates all data with reference to time and position. The complete tabulated data printout includes:

1) Date/Time - Greenwich Meridian (hours & minutes)
2) Position - Latitude and Longitude (degrees & minutes)
3) Station Number - oceanographic data station
4) Ship's heading and speed (degrees & knots)
5) Relative wind speed and direction (degrees & knots)
6) Approximate true wind speed and direction (degrees & knots)
7) Air temperature and temperature difference (°C) between 5-meter and 20-meter levels
8) Sea surface temperature (°C)
9) Sea surface salinity (parts per thousand)
10) Solar radiation in Langleys
11) Ozone - $O_3(R)$ (pphm) chemiluminescent meter reading at 10-minute intervals

12) Ozone - $\overline{O_3(R)}$,(pphm) Chemiluminescent hourly average based upon six (6) 10-minute values per hour.

13) Oxidant, $O_x(M_1)$, (pphm) Mast oxidant meter without CrO_3 scrubber, 15-minute average extracted from analog chart using equal area method (four values per hour).

14) Oxidant, $\overline{O_x(M_1)}$, (pphm) Mast oxidant meter without scrubber, hourly average based upon four (4) 15-minute values per hour.

15) Oxidant, $O_x(M_2)$, (pphm) Mast oxidant meter with CrO_3 scrubber, 15-minute average extracted from analog chart using equal area method (four values per hour).

16) Oxidant, $\overline{O_x(M_2)}$, (pphm) Mast oxidant meter with CrO_3 scrubber, hourly average based upon four (4) 15-minute values per hour.

17) Oxidant, $O_x(KI)$, (pphm) neutral buffered KI method, one hour integrated value.

18) NO, NO_2, (pphm) 2-hour integrated values, twelve per day.

19) CH_4 and CO (ppm), grab samples at 6-hour intervals.

Data considered significant to the trace gas problem are included in Appendix A. These include: date/time, position, $\overline{O_3(R)}$, $\overline{O_x(M_1)}$, $\overline{O_x(M_2)}$, $\overline{O_3(R)}/\overline{O_x(M_1)}$, $\overline{O_3(R)}/\overline{O_x(M_2)}$, CH_4, CO, and pertinent remarks.

The calibration data for the chemiluminescent meter indicated that the response characteristics remained stable throughout the cruise. Data for the coulometric meters revealed a significant variation from one calibration period to the next. These results presented a problem

regarding the selection of the most reasonable calibration factor. There was no reason to assume that the change occurred in a linear form. The decision was made to simply stratify the data by calibration period. This, of course, introduces a bias in the data; therefore, one cannot assume an accuracy greater than the difference in the calibration factors.

One of the most difficult problems involved in the measurement of atmospheric gases aboard a powered vessel is that of contamination. This problem will be discussed in more detail in Section VII. In order to minimize this problem all measurements made while the vessel was occupying an oceanographic station i.e. not underway, were deleted from the final data tabulation. There were a number of cases in which the relative wind was light, even when the ship was underway. The probability of contamination is increased under these conditions. The cases are noted in the tabulated data summary and have been designated as doubtful.

Ozone and oxidant data were collected in three of the four ports visited. These data probably reflect influences from both the ship's environment and urban activity.

SECTION VII

DISCUSSION OF RESULTS

Any discussion of the measurement and analysis of atmospheric trace gases in a marine environment must be prefaced with a discussion of the problem of contamination of the air sample by the ship's environment--if a power vessel is used. No matter how carefully one selects the position for the sampling inlet, guards against leaks in the system, and monitors the wind conditions, the possibility of contamination by engine and stack exhaust must always be considered. The local wind field is significantly influenced by the presence of the vessel. "Dead zones" are prevalent and dependent upon the relative wind vector. In an effort to minimize this problem the intake inlet was located well above the flying bridge and forward from the engine and stack exhausts. Data known to be in error due to contamination were deleted from the data tabulation summary, and doubtful data are so indicated. Having taken these precautions, it is felt that the data presented can be accepted with a reasonably high degree of confidence.

A tabulated data summary is presented in Appendix A which includes values for ozone, total oxidant, carbon monoxide, methane, and the ratio of the hourly averages of ozone to total oxidant. Methane and carbon monoxide data represent 6-hourly observations. SO_2 measurements were made, using the West & Gaeke method; however, no detectable amount was observed at any time.

The calibration data presented in Section IV indicate that the response characteristics of the chemiluminescent instrument remained

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quite stable throughout the data collection period. The calibration factor for the coulometric instruments varied by a factor of approximately two (2). This variability is reflected in a comparison between the measurements made by the two techniques in the ambient environment. The mean ratios of ozone to total oxidant, as measured by the chemiluminescent and coulometric techniques, are shown in Table III. The table includes data stratified by observation periods, as well as the mean ratio for the entire period. The values presented represent the mean of the ratio of hourly averages $\overline{O_3(R)/O_x(M_x)}$ for each stratified class interval. The mean ratios for the entire period of $\overline{O_3(R)/O_x(M_1)}$ and $\overline{O_3(R)/O_x(M_2)}$ were 0.55 and 0.63 respectively. Considering the accuracy of the techniques involved, these values do not appear to be significantly different. When the in-port data were deleted the values did not change appreciably. The ratios of individual hourly averages varied from 0.20 to 3.00. This range of variance reflects some of the variations in the actual ozone and oxidant concentrations in the ambient environment and the instability of the measurement technique. The mean value of approximately sixty (60) percent is probably representative of the actual ratio of ozone to total oxidant.

Twenty-three (23) observations of total oxidant were made using the Neutral Buffered KI Method[2] for comparison with the results obtained from both the chemiluminescent and coulometric techniques. The ratio of average hourly concentrations as measured by the chemiluminescent and coulometric techniques to the neutral KI method are shown

Table III

MEAN RATIO OF $O_3(R)/O_x(M_x)$ STRATIFIED BY CALIBRATION PERIOD

Period	$\overline{O_3(R)/O_x(M_1)}$	Number of Hourly Averages	$\overline{O_3(R)/O_x(M_1)}^*$	Number of Hourly Averages	$\overline{O_3(R)/O_x(M_2)}$	Number of Hourly Averages	$\overline{O_3(R)/O_x(M_2)}^*$	Number of Hourly Averages
June 8-June 26	0.62	180	0.62	173	0.72	228	0.73	187
June 26-July 6	0.27	221	0.28	150	0.50	220	0.68	120
July 6-July 16	0.88	107	0.88	107	0.53	116	0.53	116
July 16-July 21	0.72	83	0.74	69	0.83	95	0.85	79
	$\overline{\overline{O_3(R)/O_x(M_1)}}$		$\overline{\overline{O_3(R)/O_x(M_1)}}^*$		$\overline{\overline{O_3(R)/O_x(M_2)}}$		$\overline{\overline{O_3(R)/O_x(M_2)}}^*$	
June 8-July 21	0.55	591	0.50	499	0.63	659	0.69	502

$\overline{O_3(R)/O_x(M_1)}$ & $\overline{O_3(R)/O_x(M_2)}$ - mean ratio of hourly averages for stratified period

$\overline{O_3(R)/O_x(M_1)}^*$ & $\overline{O_3(R)/O_x(M_2)}^*$ - mean ratio of hourly averages for stratified period minus data while in port

$\overline{\overline{O_3(R)/O_x(M_1)}}$ & $\overline{\overline{O_3(R)/O_x(M_2)}}$ - mean ratio of hourly averages for entire cruise (June 8-July 21)

$\overline{\overline{O_3(R)/O_x(M_1)}}^*$ & $\overline{\overline{O_3(R)/O_x(M_2)}}^*$ - mean ratio of hourly averages for entire cruise (June 8-July 21) minus data while in port

in Table IV. The mean ratio ozone to total oxidant, $\overline{O_3(R)/O_x(KI)}$, as measured by the chemiluminescent and Neutral KI techniques, respectively, was 0.61. The value agrees well with the mean ratio of 0.55 found for the chemiluminescent and coulometric techniques. The means of the hourly ratios $\overline{O_x(M_1)}$ and $\overline{O_x(M_2)}$ to $\overline{O_x(KI)}$ were 1.50 and 1.07 respectively. These results indicate that in this relatively unpolluted environment the coulometric and Neutral KI techniques compare quite well. No obvious explanation can be given as to why the data obtained with the CrO_3 scrubber compared more favorably with the neutral KI results.

The mean ozone concentration, for the entire period, as determined by the chemiluminescent technique, was 0.5 pphm, while the mean total oxidant concentration was 1.1 pphm, 0.9 pphm, and 1.1 pphm as determined by the coulometric and neutral KI techniques. The agreement between the mean values for total oxidant is quite good.

Wartburg[5] measured total oxidant concentrations on Barbados during a period of the S.S. ADVANCE II cruise, using the Komhyr Ozone Analyzer[6]. Table V shows a comparison of a portion of the data obtained. Unfortunately the cruise track of the ADVANCE II on 25 and 26 June was such that the relative wind was rather light, hence there may have been contamination from the ship's environment. Even so, the data agree quite well.

Table IV

RATIO OF AVERAGE HOURLY CONCENTRATIONS AS MEASURED BY CHEMILUMINESCENT AND COULOMETRIC METERS TO NEUTRAL KI METHOD

$O_3(R)/O_x(KI)$	$O_x(M_1)/O_x(KI)$	$O_x(M_2)/O_x(KI)$
1.00	1.83	1.67
0.42	0.67	0.67
0.80	1.00	1.20
0.67	1.33	M
0.67	M	0.83
0.54	1.77	0.77
0.36	2.10	0.73
0.50	2.08	0.50
0.42	1.92	1.42
0.46	2.31	1.93
0.36	1.27	1.09
M	2.27	1.46
0.27	2.28	1.35
0.46	1.82	1.00
0.92	1.33	0.67
0.46	0.64	1.18
0.64	0.82	1.36
1.60	2.50	M
0.33	0.78	0.78
0.35	0.55	M
0.29	0.79	0.64
1.25	M	1.12
No. Cases 22	21	20
Average Ratio 0.61	1.50	1.07

M - Missing data

$O_3(R)$ - Chemiluminescent technique (Ozone)

$O_x(M_1)$ - Coulometric (Mast) without scrubber

$O_x(M_2)$ - Coulometric (Mast) with C_rO_3 scrubber

$O_x(KI)$ - Neutral KI Method

Table V

COMPARATIVE OXIDANT MEASUREMENTS
Island (Barbados, W.I.) vs. Sea (S. S. ADVANCE II)

Concentration in pphm

Date	Time (GMT)	Barbados* $O_x(B)$	$O_x(M_1)$	$O_x(M_2)$	$O_3(R)$	Remarks
24 June 1969	1200Z	2.4	2.5	0.8	0.6	
	2300Z	1.6	2.5	1.4	0.7	
25 June 1969	1300Z	1.4	2.4	1.8	0.4	
	2000Z	1.1	M	M	M	S.S. ADVANCE II on station. Relative wind light. Possible contamination on 25 and 26 June.
26 June 1969	1400Z	1.3	3.0	2.5	0.6	

*Measurements provided by Messrs. John Pate and Arthur Wartburg, NCAR, Boulder, Colorado. Instrument used - Komhyr Ozone Analyzer (Total Oxidant)

A careful examination of all of the ozone and total oxidant data collected during the cruise did not reveal any evidence of a systematic variation in concentration with latitude. Assuming no latitudinal dependence, one should be able to determine whether or nor there was a significant diurnal trend in the ozone and oxidant concentrations, such as is normally found in continental areas. Values representing a diurnal mean curve for $O_3(R)$, $O_x(M_1)$, and $O_x(M_2)$ are shown in Tables VI and VII. It should be noted again that these values do not represent actual temporal changes at a given location, since all reliable measurements were used, without regard to position, in computing the means. The data do not reflect a detectable diurnal variation in either ozone or total oxidant. A possible explanation would be the absence of the necessary precursors, or vertical transport due to diurnal atmospheric instability. Based upon these results, conclusions involving photochemical processes in the atmospheric boundary layer over continental areas, and urban regions in particular, cannot be extrapolated with confidence to the marine environment. It should be noted that data reported here were taken during the early summer. The mean concentrations were lower than expected--based upon the continental data available. These data may not be representative of other seasons, and other regions of the oceans. Oxidant measurements made on two cruises of the Duke University R/V EASTWARD in the spring season, on an approximate east-west track from Cape Lookout, revealed higher concentrations (3 to 5 pphm) than were observed on the cruise to the equator.

Facilities for <u>in situ</u> analyses of carbon monoxide (CO) and methane were not available aboard the ADVANCE II. Samples were collected

Table VI

DIURNAL MEAN OZONE [O_3(R)] CONCENTRATION

S. S. ADVANCE II BOMEX CRUISE
Period - 8 June through 21 July 1969

Hour (GMT)	$\overline{O_3(R)}$ pphm	No. Cases
0000	0.52	30
0100	0.54	34
0200	0.52	32
0300	0.55	29
0400	0.52	31
0500	0.51	27
0600	0.55	26
0700	0.54	30
0800	0.54	30
0900	0.52	30
1000	0.50	28
1100	0.53	29
1200	0.51	29
1300	0.52	33
1400	0.50	32
1500	0.50	30
1600	0.50	25
1700	0.52	29
1800	0.50	35
1900	0.50	31
2000	0.50	28
2100	0.57	33
2200	0.56	30
2300	0.54	29

NOTE: It should be recognized that these values do not represent temporal changes at a given location, since all reliable measurements were used in computing the means without regard to position. This assumes no significant latitudinal variation.

Table VII

DIURNAL MEAN OXIDANT [$O_x(M_x)$] CONCENTRATION
S. S. ADVANCE II BOMEX CRUISE
Period - 8 June through 21 July 1969

Mean O_x Concentration in pphm

Hour (GMT)	$\overline{O_x(M_1)}$	No. Cases	$\overline{O_x(M_2)}$	No. Cases
0000	1.1	31	0.9	33
0100	1.2	34	0.9	38
0200	1.1	32	0.9	36
0300	1.0	30	0.8	33
0400	1.0	32	0.8	35
0500	1.2	33	0.9	35
0600	1.2	35	1.0	38
0700	1.2	35	0.9	38
0800	1.2	32	0.9	37
0900	1.2	33	1.0	37
1000	1.1	33	1.0	35
1100	1.1	34	0.9	37
1200	1.2	31	0.9	35
1300	1.2	35	0.9	38
1400	1.2	36	0.9	35
1500	1.3	29	0.9	35
1600	1.2	26	0.9	30
1700	1.1	29	0.8	31
1800	1.1	35	0.9	36
1900	1.0	32	0.8	31
2000	1.1	32	0.8	32
2100	1.1	33	0.8	35
2200	1.1	33	0.9	36
2300	1.0	31	0.9	33

NOTE: It should be recognized that these values do not represent temporal changes at a given location, since all reliable measurements were used in computing the means without regard to position. This assumes no significant latitudinal variation.

in evacuated grab sample bottles and returned to NAPCA for analysis by Ortman. Results of these analyses are included in Appendix A. Background CH_4 concentrations of approximately 1.2-1.4 ppm were observed. Carbon monoxide concentrations ranged from 0.06 to 0.92 ppm with a mean of 0.18. The data do not indicate any significant latitudinal dependence. These values compare quite favorably with those found by Swinnerton et al. [7] during a cruise in June 1968 along a similar track (CH_4 - 1.24 $\pm$ 0.03 ppm; CO - 0.075 to 0.44 pm).

Two-hour and 24-hour integrated sulfur dioxide (SO_2) samples were collected throughout the duration of the cruise using the West & Gaeke Method[2]. No detectable amount of SO_2 was observed at any time during the cruise, therefore, no data are presented in the tabulated section of Appendix A. Pate et al.[5] made simultaneous measurements for SO_2 on the island of Barbados,while the S.S. ADVANCE II was off the northern coast, and found no detectable amount. Further, measurements made in this area over the past 3 years by Pate have failed to reveal a detectable concentration of SO_2.

Oxides of nitrogen data (NO, NO_2) were collected using the Saltzman Method[2]. Concentrations found ranged from 1 to 30 ppb. Pate et al.[4] reported NO_x concentration values in approximately the same range.

Since the mean oxidant concentration was approximately twice the mean ozone concentration, one might speculate as to the presence of other oxidants in a marine environment. Obviously, oxides of nitrogen contribute to the oxidant background, as measured by the coulometric and neutral KI techniques. This contribution is not

enough, however, to explain the difference. Chlorine probably contributes to some extent to the total oxidant concentration in a marine environment. The Mast meter will respond to chlorine in the same molar relationship as it does to ozone. Junge[8] reports values of chlorine of approximately 1 ppb along the coast of Florida. This would contribute to, but not account for, the difference observed between ozone and total oxidant.

Altshuller, et al.[9] have shown that oxidant concentration in urban environments is significantly dependent upon photochemical processes involving hydrocarbons and oxides of nitrogen. The results presented indicate that a reduction in oxidant concentration in the urban environment may require a high degree of control of hydrocarbons and nitrogen oxide. Control of olefins and alkylebenzenes was shown to effectively reduce ozone. The low concentrations of ozone and oxidants observed in the marine environment tend to support these findings.

If during the observation period reported upon, the synthesis of ozone in the marine atmosphere boundary layer by photochemical processes was insignificant, then the observed concentrations would be primarily dependent upon vertical transport and diffusion from the stratosphere. The concentration in the atmospheric layer near the surface of the water would then be the result of existing atmospheric conditions and the destruction processes at or near the surface. The air and water temperature measurements taken aboard the ADVANCE II indicate that an inversion existed a large percentage of the time. This would tend to inhibit the downward diffusion of ozone, hence would result in a lower concentration.

During a major portion of the cruise, the weather conditions were quite typical of conditions ascribed to the western side of the sub-tropical high pressure ridge. With the exception of a few cases of mid-latitude frontal penetration, the Bermuda high was centered near 30°N 45°W with variation of 5° north and south or east and west. The basic wind field in the tropics was east-southeasterly and becoming more southerly in the higher latitudes.

Near the equator the wind flow appeared to come under the influence of a weak cyclonic circulation along the northeastern Brazil coast. The position of the center of this circulation changed with the movement of the intertropical convergence zone (ITCZ). It is estimated that the ITCZ was near 7°N when the ADVANCE II traversed it.

Cloud coverage varied from clear to overcast and was not persistent. The lower clouds, principally cumulus of moderate vertical extent mixed with some stratocumulus, had bases near 500 meters in most cases. In showers, their bases were near 300 meters. Altocumulus and cirrus were frequently present and quite variable in coverage.

Only two organized weather systems were encountered. The first system was a decaying tropical depression associated with a persistent trough oriented NE-SW through the Florida Straits. Effects of this system were encountered soon after leaving Wilmington, North Carolina and persisted until the southeasterly trade flow was encountered on June 12.

The second system was a tropical depression which moved rapidly across the BOMEX observation area June 20 and 21. Rain was encountered at other times and would be visible in the distance. However, most of it was associated with tropical shower activity.

SECTION VIII

SUMMARY AND CONCLUSIONS

Ozone and total oxidant were measured simultaneously in a marine environment using chemiluminescent and coulometric techniques. The neutral KI technique served as the reference method for calibration using a constant ozone source. The data reveal that the response of the KI and coulometric techniques are similar in an unpolluted environment. For the purpose of determining long term mean concentrations the coulometric technique yields useful results; however, errors of $\pm$ 100 percent can be expected for individual measurements. The results indicate that the chemiluminescent technique is a reliable method of measuring ozone at low atmospheric concentrations, such as those found in a marine environment.

The mean values found for the period indicate that ozone constituted 60 percent of total oxidant concentration. The mean concentration of ozone was 0.5 pphm. The mean total oxidant concentration was approximately 0.9 pphm. Approximately 0.4 pphm represents unknown oxidants. The concentration of nitrogen dioxide as measured by the Saltzman technique was not sufficient to account for the difference between ozone and total oxidant.

The average measured concentrations of methane and carbon monoxide were 1.36 and 0.18 ppm respectively. Again, analysis of the data did not reveal any evidence of significant latitudinal dependence or diurnal trends. The data suggest some possible correlation with water depths; however, this was not examined in detail. The relationship between the

the concentration of CO and CH_4 in the air and water will require a great deal of study.

The data do not reveal a diurnal trend in ozone or total oxidant concentration, such as that observed in continental areas. This suggests that photochemical reactions and vertical transport near the surface of the sea were at a minimum. A feasible explanation for the low level of photochemical activity would be the absence of the ozone and oxidant precursors. It should be pointed out that these data are representative only of ozone and oxidant in the early summer season. Seasonal variations may be of importance.

No significant evidence of urban pollution from the United States or other continents was detected at sea during this cruise. The mean values presented for ozone, total oxidant, carbon monoxide, and methane are considered representative of the geophysical background levels for the region during early summer.

The results of this study emphasize the difficulty in attempting to extrapolate from a local pollutant system, such as an isolated continental or urban area, to a global system. The urgent need for in-depth baseline studies is apparent.

SECTION IX

RECOMMENDATIONS FOR FUTURE WORK

The results of the comparison study between the chemiluminescent and coulometric techniques for measuring ozone and total oxidant at low atmospheric concentrations indicate a significant difference in the chemistry of atmospheric pollutants between continental and marine environments. These differences may be extremely important to the overall problem of air pollution from urban sources and its ultimate effect. In order to achieve a better understanding of the role of the oceans in the problem of air pollution the following studies are recommended:

1) Determine seasonal and spatial concentration distributions in the marine environment for the trace gases which are normally considered indices of air quality.
2) Determine the extent to which pollutants from a given urban source penetrate the marine atmospheric boundary layer.
3) Conduct a study to identify and quantitate the major oxidants other than ozone in a marine environment.
4) Investigate the diurnal behavior of individual oxidants, including ozone, in the marine environment.
5) Investigate the role of the oceans in the carbon monoxide cycle.

SECTION X

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APPENDIX A

TABULATED DATA SUMMARY
S. S. ADVANCE II Cruise
Period - 8 June through 21 July 1969

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EXPLANATORY NOTES

1. Parameter Designators:

$O_3(R)$	Chemiluminescent hourly average concentration in pphm (parts per hundred million) based upon six (6) 10-minute values per hour.
$O_X(M_1)$	Mast oxidant meter without CrO_3 scrubber, hourly average concentrations based upon four (4) 15-minute values per hour.
$O_X(M_2)$	Mast oxidant meter with CrO_3 scrubber, hourly average concentrations based upon four (4) 15-minute values per hour.
$O_3(R)/O_x(M_1)$	Ratio of hourly averages for $O_3(R)$ and $O_x(M_1)$, as defined above, in percent.
$O_3(R)/O_x(M_2)$	Ratio of hourly averages for $O_3(R)$ and $O_x(M_2)$, as defined above, in percent.
CH_4	Methane concentration in ppm.
CO	Carbon monoxide concentration in ppm
GMT	Greenwich Meridian Time
$O_X(KI)$	Oxidant concentration in pphm obtained by neutral buffered KI method.
M	Missing data.

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Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
June 8, 1969

Hour GMT	Position Lat.	Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000										
0100										
0200										
0300										
0400										
0500										
0600										
0700										
0800										
0900										
1000										
1100										
1200										
1300										
1400										
1500										
1600										
1700										
1800	33°12' N	77°45' W	0.9	1.1	1.8	82	50			Calibrated all oxidant and ozone instruments against neutral KI using control ozone source.
1900	33°01'	77°32'	0.7	0.9	1.5	78	40			
2000	32°50'	77°25'	0.7	1.0	1.5	70	47			
2100	32°46'	77°10'	M	M	M	M	M			
2200	32°40'	77°02'	0.3	0.4	0.9	75	33	M	M	
2300	32°33'	76°55'	0.3	0.3	1.0	100	30			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
June 9, 1969

Hour GMT	Position Lat.	Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	32°25'N	76°47'W	0.4	0.5	1.0	80	40			
0100	32°14'	76°40'	0.6	0.6	1.1	100	55			
0200	32°01'	76°30'	0.6	0.6	1.1	100	55			
0300	31°49'	76°26'	0.5	0.6	1.1	83	45			
0400	31°38'	76°23'	0.4	0.7	1.1	57	36	M	M	
0500	31°30'	76°20'	M	M	M	M	M			
0600	31°29'	76°18'	0.6	0.8	1.3	75	46			
0700	31°15'	76°12'	0.6	0.8	1.3	75	46			
0800	31°01'	76°05'	0.5	0.7	1.2	71	42			
0900	30°47'	75°56'	0.6	0.8	1.3	75	46			
1000	30°34'	75°49'	0.5	0.6	1.3	83	38	M	M	
1100	30°21'	75°34'	0.6	0.8	1.3	75	46			
1200	30°10'	75°26'	0.7	0.8	1.2	87	58			
1300	29°56'	75°15'	0.6	0.7	1.1	86	55			
1400	29°45'	75°09'	0.5	0.7	1.0	71	50			
1500	29°34'	75°00'	0.4	0.6	0.9	67	44			
1600	29°22'	74°49'	0.2	0.6	0.7	33	28	M	M	
1700	29°11'	74°43'	0.3	0.5	0.7	60	43			
1800	29°00'	74°39'	M	M	M	M	M			
1900	28°55'	74°37'	0.4	0.8	0.6	50	67			
2000	28°47'	74°32'	0.2	0.7	0.6	29	33			
2100	28°36'	74°26'	0.3	0.7	0.6	43	50			
2200	28°25'	74°18'	0.5	0.8	0.7	62	71	1.35	0.12	
2300	28°13'	74°71'	0.5	0.9	0.9	55	55			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
June 10, 1969

Hour GMT	Position Lat.	Long.	$O_3(R)$ pphm	$O_X(M_1)$ pphm	$O_X(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	28°04'N	74°05'W	0.6	1.0	1.1	60	55			
0100	27°55'	73°57'	M	M	M	M	M			
0200	27°46'	73°52'	0.5	1.0	1.0	50	50			
0300	27°34'	73°46'	0.5	1.0	1.1	50	46			
0400	27°26'	73°37'	0.5	0.9	1.0	55	50	1.34	.30	
0500	27°15'	73°32'	0.5	0.8	1.0	62	50			
0600	27°04'	73°25'	0.5	0.9	1.0	55	50			
0700	26°51'	73°24'	0.6	0.9	1.2	67	50			
0800	26°41'	73°16'	0.8	1.1	1.6	73	50			
0900	26°31'	73°08'	M	M	M	M	M			
1000	26°22'	73°01'	0.6	1.2	1.3	50	46	1.36	.22	
1100	26°12'	72°55'	0.6	1.0	1.1	60	55			
1200	26°00'	72°49'	0.5	0.9	1.0	55	50			
1300	25°47'	72°39'	0.5	0.8	1.0	62	50			
1400	25°33'	72°29'	0.5	0.8	0.9	62	55			
1500	25°21'	72°22'	0.5	0.7	1.0	71	50			
1600	25°13'	72°15'	M	M	M	M	M	1.38	.49	
1700	25°13'	72°15'	M	M	M	M	M			
1800	25°12'	72°15'	0.6	0.9	0.7	67	86			
1900	25°08'	72°11'	0.8	1.0	1.0	80	80			
2000	24°58'	72°06'	0.7	1.0	1.0	70	70			
2100	24°48'	71°59'	0.9	1.2	1.2	75	75			
2200	24°37'	71°52'	0.8	1.3	1.3	62	62	1.36	.18	
2300	24°27'	71°46'	0.9	1.3	1.3	69	69			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
June 11, 1969

Hour GMT	Position Lat.	Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	24°17'N	71°39'W	0.6	0.9	1.0	67	60			
0100	24°06'	71°32'	0.5	0.7	0.7	71	71			
0200	23°56'	71°26'	0.6	0.9	0.8	67	75			
0300	23°44'	71°19'	0.6	0.9	0.8	67	75			
0400	23°32'	71°11'	0.6	0.9	0.8	67	75	1.30	.14	
0500	23°21'	71°04'	0.7	0.9	0.9	78	78			
0600	22°06'	71°00'	0.7	1.1	1.1	64	64			
0700	22°50'	70°55'	0.4	0.7	0.7	57	57			
0800	22°44'	70°33'	0.4	0.6	0.5	67	80			
0900	22°34'	70°24'	0.3	0.6	0.5	50	60			
1000	22°22'	70°19'	0.3	0.5	0.5	60	60	1.30	.19	
1100	22°09'	70°12'	M	0.5	0.5	M	M			
1200	21°56'	70°06'	0.2	0.5	0.5	40	40			
1300	21°44'	70°02'	0.3	0.5	0.4	60	75			
1400	21°30'	69°56'	0.2	0.4	0.4	50	50			
1500	21°21'	69°51'	0.1	0.6	0.2	17	50			
1600	21°15'	69°48'	M	M	M	M	M	1.32	.23	
1700	21°16'	69°48'	M	M	M	M	M			
1800	21°16'	69°42'	0.3	0.5	0.2	60	150			
1900	21°14'	69°30'	0.4	0.4	0.2	100	200			
2000	21°11'	67°22'	0.4	0.4	0.2	100	200			
2100	21°05'	69°08'	0.2	0.5	0.2	40	100			
2200	21°01'	68°56'	0.3	0.5	0.2	60	150	1.24	.14	
2300	20°55'	68°44'	0.3	0.5	0.2	60	150			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
June 12, 1969

Hour GMT	Position Lat.	Position Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	20°51'N	68°31'W	0.3	0.5	0.2	60	150			
0100	20°48'	68°25'	0.3	0.6	0.2	50	150			
0200	20°41'	68°17'	0.4	0.6	0.2	67	200			
0300	20°34'	68°06'	0.4	0.6	0.2	67	200			
0400	20°29'	67°54'	0.3	0.6	0.2	50	150	M	M	
0500	20°24'	67°40'	0.5	0.6	0.4	83	125			
0600	20°20'	67°28'	0.5	0.7	0.6	71	83			
0700	20°16'	67°19'	0.3	0.6	0.6	50	50			
0800	20°13'	67°11'	0.1	0.6	0.6	17	17			
0900	20°17'	67°08'	M	M	M	M	M			
1000	20°21'	67°06'	M	M	M	M	M	1.30	.13	
1100	20°19'	66°56'	0.3	0.6	0.5	50	60			
1200	20°21'	66°42'	0.2	0.5	0.5	40	40			
1300	20°16'	66°29'	0.3	0.7	0.6	43	50			
1400	20°15'	66°20'	0.5	0.6	0.7	83	71			
1500	20°16'	66°03'	0.4	0.6	0.6	67	67			
1600	20°09'	65°50'	0.3	0.5	0.5	60	60	1.39	.15	
1700	20°07'	65°37'	0.3	0.4	0.4	75	75			
1800	20°02'	65°25'	0.2	0.5	0.4	40	50			
1900	19°55'	65°16'	0.2	0.6	0.5	33	40			
2000	19°47'	65°00'	0.4	0.6	0.5	67	80			
2100	19°41'	64°57'	0.4	0.8	0.7	50	57			
2200	19°34'	64°47'	0.5	0.8	0.7	63	71	1.34	.13	
2300	19°26'	64°37'	0.5	0.7	0.8	71	63			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
June 13, 1969

Hour GMT	Position Lat.	Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	19°19'N	64°26'W	0.5	0.8	0.8	63	63			
0100	19°14'	64°15'	0.6	0.8	0.8	75	75			
0200	19°08'	64°15'	0.4	0.7	0.6	57	67			
0300	19°01'	63°55'	0.4	0.8	0.7	50	57			
0400	18°56'	63°43'	0.5	0.7	0.7	71	71	1.39	.16	
0500	18°50'	63°32'	0.5	0.7	0.7	71	71			
0600	18°43'	63°20'	0.5	0.8	0.8	63	63			
0700	18°38'	63°09'	0.5	0.9	0.8	56	63			
0800	18°31'	62°57'	0.7	1.0	1.0	70	70			
0900	18°24'	62°45'	0.6	1.1	1.0	55	60			
1000	18°18'	62°32'	0.5	1.1	1.0	45	50	1.34	.10	
1100	18°13'	62°20'	0.6	1.0	1.0	60	60			
1200	18°07'	62°09'	0.4	1.0	1.0	40	40			
1300	18°01'	61°58'	0.6	1.0	1.0	60	60			
1400	17°55'	61°49'	0.6	1.1	1.0	55	60			$O_x(KI)$ - 0.6 pphm
1500	17°48'	61°35'	0.6	1.0	0.9	60	67			
1600	17°43'	61°25'	M	0.9	0.8	M	M	1.32	.08	
1700	17°39'	61°26'	M	M	M	M	M			
1800	17°39'	61°26'	M	M	M	M	M			
1900	17°35'	61°24'	M	0.8	M	M	M			
2000	17°25'	61°23'	M	0.7	M	M	M			
2100	17°21'	61°23'	M	0.8	M	M	M			
2200	17°11'	61°22'	M	0.6	M	M	M	1.32	.10	
2300	17°03'	61°23'	M	M	M	M	M			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
June 14, 1969

Hour GMT	Position Lat.	Position Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	16°56'N	61°27'W	0.1	M	M	M	M			
0100	16°52'	61°35'	0.1	M	M	M	M			
0200	16°49'	61°42'	0.2	M	M	M	M			
0300	16°45'	61°50'	0.7	M	M	M	M			
0400	16°40'	61°58'	0.0	M	M	M	M	1.23	.36	
0500	16°34'	62°06'	0.0	M	M	M	M			
0600	16°30'	62°12'	0.1	M	M	M	M			
0700	16°28'	62°18'	0.3	M	M	M	M			
0800	16°20'	62°20'	0.6	1.0	1.1	60	55			
0900	16°13'	62°18'	0.5	1.1	1.2	45	42			
1000	16°06'	62°13'	0.6	1.1	1.2	55	50	1.32	.06	
1100	16°00'	62°09'	0.6	1.0	1.1	60	55			
1200	15°52'	62°05'	0.6	1.0	1.1	60	55			
1300	15°45'	62°02'	0.6	1.1	1.2	55	50			
1400	15°45'	61°54'	M	0.8	0.9	M	M			
1500	15°45'	61°45'	0.5	0.8	0.8	63	63			O_x(KI) - 1.2 pphm
1600	15°40'	61°39'	0.6	0.9	0.8	67	75	1.42	.46	
1700	15°45'	61°30'	0.5	0.8	0.8	63	63			
1800	15°45'	61°22'	0.6	0.8	0.8	75	75			
1900	15°45'	61°13'	0.6	0.9	0.9	67	67			
2000	15°45'	61°05'	0.5	1.0	1.0	50	50			
2100	15°44'	60°56'	0.7	1.1	1.3	64	54			
2200	15°44'	60°47'	0.5	0.9	1.0	56	50	1.39	.10	
2300	15°42'	60°39'	0.6	0.9	0.9	67	67			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
June 15, 1969

Hour GMT	Position Lat.	Position Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	15°41'N	60°31'W	0.7	0.8	0.9	87	78			
0100	15°39'	60°22'	0.6	0.7	0.8	86	75			
0200	15°38'	60°16'	0.5	0.7	0.8	71	63			
0300	15°37'	60°14'	0.5	0.7	0.8	71	63			
0400	15°36'	60°11'	0.4	0.7	0.8	57	50	1.36	.13	
0500	15°36'	60°04'	0.5	0.9	0.9	56	56			
0600	15°36'	59°59'	0.6	1.0	1.0	60	60			
0700	15°37'	59°52'	0.6	0.9	1.0	67	60			
0800	15°36'	59°47'	0.6	0.9	1.0	67	60			
0900	15°34'	59°40'	0.4	0.9	1.0	44	40			
1000	15°33'	59°34'	0.5	0.9	1.0	56	50	1.36	.40	
1100	15°25'	59°33'	0.5	0.8	1.0	63	50			
1200	15°22'	59°32'	0.3	0.5	0.8	60	38			
1300	15°19'	59°34'	0.6	0.7	0.7	86	86			
1400	15°15'	59°38'	0.3	0.7	0.7	43	43			
1500	15°11'	59°40'	0.4	0.5	0.6	80	67			$O_x(KI)$ - 0.5 pphm
1600	15°07'	59°42'	0.4	M	0.6	M	67	1.34	.14	
1700	14°58'	59°47'	0.3	0.6	0.6	50	50			
1800	14°47'	59°54'	0.3	0.6	0.6	50	50			
1900	14°37'	60°00'	0.4	0.6	0.6	67	67			
2000	14°27'	60°06'	0.3	0.6	0.6	50	50			
2100	14°16'	60°13'	0.4	0.6	0.6	67	67			
2200	14°04'	60°20'	0.3	0.6	0.7	50	43	1.38	.96	
2300	13°56'	60°27'	0.3	0.6	0.7	50	43			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
June 16, 1969

Hour GMT	Position Lat.	Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	13°53'N	60°31'W	0.4	0.5	0.8	80	50			
0100	13°41'	60°36'	0.4	0.5	0.7	80	57			
0200	13°30'	60°35'	0.4	0.8	0.7	50	57			
0300	13°31'	60°31	0.4	0.8	0.8	50	50			
0400	13°32'	60°30'	0.4	0.9	0.8	44	50	1.36	.14	
0500	13°33'	60°25'	0.5	0.9	0.8	56	63			
0600	13°33'	60°19'	0.5	1.0	0.8	50	63			
0700	13°33'	60°15'	0.5	1.1	0.8	45	63			
0800	13°33'	60°10'	0.5	1.0	0.8	50	63			
0900	13°32'	60°05'	0.4	1.0	0.8	40	50			
1000	13°33'	59°59'	0.4	1.1	0.8	36	50	M	M	
1100	13°33'	59°53'	0.5	1.1	0.8	45	63			
1200	13°32'	59°48'	0.5	1.1	0.8	45	63			
1300	13°31'	59°43'	0.5	1.3	M	38	M			
1400	13°31'	59°37'	0.6	1.2	M	50	M			
1500	13°30'	59°23'	0.6	1.2	M	50	M			$O_x(KI)$ - 0.9 pphm
1600	13°30'	59°19'	0.6	1.2	M	50	M	1.36	.12	
1700	13°31'	59°15'	0.4	1.1	M	36	M			
1800	13°31'	59°09'	0.7	1.1	M	64	M			
1900	13°30'	59°04'	0.6	1.1	M	55	M			
2000	13°30'	59°04'	0.5	1.2	M	42	M			
2100	13°29'	59°00'	0.5	M	M	M	M			
2200	13°21'	59°02'	0.6	M	M	M	M	1.40	1.42	
2300	13°14'	59°03'	0.4	M	M	M	M			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
June 17, 1969

Hour GMT	Position Lat.	Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	13°05'N	59°00'W	0.5	M	M	M	M			
0100	12°55'	59°00'	0.5	M	M	M	M			
0200	12°47'	59°00'	0.6	M	M	M	M			
0300	12°42'	59°05'	0.6	M	M	M	M			
0400	12°42'	59°11'	0.5	M	M	M	M	1.42	.57	
0500	12°42'	59°21'	0.5	M	M	M	M			
0600	12°43'	59°31'	0.4	M	M	M	M			
0700	12°46'	59°42'	0.4	M	M	M	M			
0800	12°50'	59°43'	0.4	M	M	M	M			
0900	13°00'	59°46'	0.3	M	M	M	M			
1000	13°02'	59°42'	0.3	M	M	M	M	M	M	
1100	13°04'	59°39'	0.3	M	M	M	M			
1200	13°06'	59°36'	0.2	M	0.7	M	M			In port (Barbados)
1300	13°06'	59°36'	0.3	0.9	0.6	33	50			
1400	13°06'	59°36'	0.3	0.6	0.6	50	50			
1500	13°06'	59°36'	0.3	0.6	0.6	50	50			
1600	13°06'	59°36'	0.3	0.6	0.6	50	50	M	M	
1700	13°06'	59°36'	0.2	0.6	0.5	33	40			
1800	13°06'	59°36'	0.3	0.8	0.5	38	60			
1900	13°06'	59°36'	0.3	0.7	0.5	43	60			
2000	13°06'	59°36'	M	0.7	0.5	M	M			
2100	13°06'	59°36'	M	0.7	0.5	M	M			
2200	13°06'	59°36'	M	0.7	0.5	M	M	M	M	
2300	13°06'	59°36'	M	0.7	0.4	M	M			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
June 18, 1969

Hour GMT	Position Lat.	Position Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	13°06'N	59°36'W	M	0.7	0.4	M	M			
0100	13°06'	59°36'	M	0.7	0.4	M	M			
0200	13°06'	59°36'	M	0.7	0.4	M	M			
0300	13°06'	59°36'	M	0.7	0.4	M	M			
0400	13°06'	59°36'	M	0.7	0.4	M	M	M	M	
0500	13°06'	59°36'	M	0.7	0.4	M	M			
0600	13°06'	59°36'	M	0.7	0.5	M	M			
0700	13°06'	59°36'	0.3	M	0.5	M	60			
0800	13°06'	59°36'	0.3	M	0.5	M	60			
0900	13°06'	59°36'	0.2	M	0.5	M	40			
1000	13°06'	59°36'	0.3	M	0.5	M	60	M	M	
1100	13°06'	59°36'	0.4	M	0.5	M	80			
1200	13°06'	59°36'	0.6	M	0.6	M	100			
1300	13°06'	59°36'	0.5	M	0.6	M	83			
1400	13°06'	59°36'	0.4	M	0.6	M	67			
1500	13°06'	59°36'	0.4	M	0.6	M	67			
1600	13°06'	59°36'	0.3	M	0.6	M	50	M	M	
1700	13°06'	59°36'	0.3	M	0.6	M	50			
1800	13°06'	59°36'	0.3	M	0.6	M	50			
1900	13°06'	59°36'	0.4	M	0.6	M	67			
2000	13°06'	59°36'	0.3	M	0.6	M	50			
2100	13°06'	59°36'	0.5	M	0.6	M	83			
2200	13°06'	59°36'	0.4	M	0.6	M	67	M	M	
2300	13°06'	59°36'	0.3	M	0.6	M	50			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
June 19, 1969

Hour GMT	Position Lat.	Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	13°06'N	59°36'W	0.4	M	0.6	M	67			
0100	13°06'	59°36'	0.5	M	0.5	M	100			
0200	13°06'	59°36'	0.4	M	0.5	M	80			
0300	13°06'	59°36'	0.4	M	0.5	M	80			
0400	13°06'	59°36'	0.5	M	0.5	M	100	M	M	
0500	13°06'	59°36'	0.4	M	0.5	M	80			
0600	13°06'	59°36'	0.4	M	0.5	M	80			
0700	13°06'	59°36'	0.3	M	0.5	M	60			
0800	13°06'	59°36'	0.3	M	0.6	M	50			
0900	13°06'	59°36'	0.4	M	0.6	M	67			
1000	13°06'	59°36'	0.4	M	0.6	M	67	M	M	
1100	13°06'	59°36'	0.3	M	0.6	M	50			
1200	13°06'	59°36'	0.4	M	0.6	M	67			
1300	13°06'	59°36'	0.5	M	0.6	M	83			
1400	13°06'	59°36'	0.3	M	0.6	M	50			
1500	13°06'	59°36'	0.4	M	0.5	M	80			
1600	13°06'	59°36'	0.4	M	0.5	M	80	M	M	
1700	13°05'	59°42'	0.4	M	M	M	M			Last Measurement In Port(Barbados) $O_x(KI)$ - 0.6 pphm
1800	13°00'	59°35'	0.5	M	0.4	M	125			
1900	12°50'	59°23'	0.6	M	0.4	M	150			
2000	12°40'	59°15'	0.6	M	0.3	M	200			
2100	12°35'	59°06'	0.5	M	0.2	M	250			
2200	12°31'	59°01'	M	M	M	M	M	M	M	
2300	12°31'	59°01'	M	M	M	M	M			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
June 20, 1969

Hour GMT	Position Lat.	Position Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	12°31'N	59°01'W	M	M	M	M				
0100	12°38'	59°00'	0.4	M	0.3	M	133			
0200	12°50'	59°00'	0.5	M	0.4	M	125			
0300	13°00'	59°00'	M	M	M	M	M			
0400	13°00'	59°00'	M	M	M	M	M	1.27	.08	
0500	13°00'	59°00'	M	M	M	M	M			
0600	13°03'	59°00'	0.5	M	0.3	M	167			
0700	13°11'	59°01'	0.6	M	0.5	M	120			
0800	13°23'	59°03'	0.6	M	0.6	M	100			
0900	13°30'	59°00'	M	M	M	M	M			
1000	13°30'	59°00'	M	M	M	M	M	M	M	
1100	13°30'	59°00'	M	M	M	M	M			
1200	13°37'	59°00'	0.5	M	0.4	M	125			
1300	13°47'	59°00'	0.7	M	0.4	M	175			
1400	13°58'	59°00'	M	M	M	M	M			
1500	14°00'	59°00'	M	M	M	M	M			$O_x(KI)$ - 1.1 pphm
1600	13°58'	59°00'	M	M	M	M	M	1.34	.46	
1700	14°07'	59°00'	0.5	0.7	0.2	71	250			
1800	14°17'	59°00'	0.4	0.6	0.2	67	200			
1900	14°28'	59°00'	0.5	0.6	M	83	M			
2000	14°30'	59°00'	M	M	M	M	M			
2100	14°32'	59°01'	0.4	0.7	M	57	M			
2200	14°45'	59°01'	0.5	0.6	0.5	83	100	1.42	.26	
2300	15°02'	58°58'	0.5	0.6	0.5	83	100			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
June 21, 1969

Hour GMT	Position Lat.	Position Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	15°00'N	59°00'W	M	M	M	M	M			
0100	15°00'	59°00'	0.4	0.7	0.6	57	67			
0200	15°00'	59°00'	0.6	M	0.6	M	100			
0300	15°00'	59°00'	0.5	M	0.5	M	100			
0400	15°24'	59°04'	0.6	M	0.6	M	100	1.28	1.20	
0500	15°30'	59°00'	M	M	M	M	M			
0600	15°30'	59°00'	M	M	M	M	M			
0700	15°30'	59°08'	0.6	M	0.6	M	100			
0800	15°45'	59°04'	0.6	M	0.6	M	100			
0900	16°02'	59°00'	0.5	M	0.6	M	83			
1000	16°02'	58°59'	M	M	M	M	M	1.46	.14	
1100	16°02'	58°59'	M	M	M	M	M			
1200	16°02'	58°59'	M	M	M	M	M			
1300	16°12'	59°00'	0.6	M	0.6	M	100			
1400	16°26'	59°00'	M	M	M	M	M			
1500	16°30'	59°00'	M	M	M	M	M			$O_x(KI)$ - 0.8 pphm
1600	16°30'	59°00'	M	M	M	M	M	1.40	.18	
1700	16°40'	59°00'	0.4	M	0.5	M	80			
1800	16°55'	59°00'	0.5	0.6	0.5	83	100			
1900	17°00'	59°00'	M	M	M	M	M			
2000	17°00'	59°00'	M	M	M	M	M			
2100	17°02'	59°00'	0.6	0.5	0.7	120	86			
2200	17°16'	58°58'	0.5	0.5	0.7	100	71	1.34	.49	
2300	17°29'	58°57'	1.0	1.0	M	100	M			New calibration value used for oxidant and ozone.

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
June 22, 1969

Hour GMT	Position Lat.	Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	17°30'	59°00'	M	M	M		M			New calibration value used for oxidant and ozone.
0100	17°33'	58°58'	M	M	M	M	M			
0200	17°24'	58°56'	0.7	1.5	1.0	47	70			
0300	17°16'	58°43'	0.5	1.6	1.0	31	50			
0400	17°10'	58°34'	0.6	1.8	1.0	33	60	1.36	.13	
0500	17°04'	58°26'	0.6	2.0	1.0	30	60			
0600	16°58'	58°17'	0.5	2.1	1.2	24	42			
0700	16°51'	58°09'	0.6	2.3	1.2	26	50			
0800	16°44'	58°01'	0.8	2.3	1.2	35	67			
0900	16°36'	57°51'	0.7	2.3	1.2	30	58			
1000	16°29'	57°43'	0.6	2.3	1.2	26	50	M	M	
1100	16°22'	57°34'	0.6	2.5	1.2	24	50			
1200	16°15'	57°25'	0.6	2.5	1.2	24	50			
1300	16°08'	57°17'	0.6	2.5	1.2	24	50			
1400	16°01'	57°08'	0.5	2.4	1.2	21	42			
1500	15°55'	56°59'	0.7	2.3	1.0	30	70			$O_x(KI)$ - 1.3 pphm
1600	15°48'	56°50'	0.6	2.3	1.0	26	60	1.40	1.60	
1700	15°40'	56°42'	0.5	2.3	1.0	22	50			
1800	15°33'	56°33'	0.5	2.4	0.8	21	63			
1900	15°26'	56°24'	0.5	2.5	0.8	20	63			
2000	15°19'	56°16'	0.6	2.5	0.8	24	75			
2100	15°11'	56°08'	0.5	2.5	0.8	20	63			
2200	15°04'	55°58'	0.4	2.5	0.8	16	50	M	M	
2300	14°57'	55°48'	0.5	2.5	0.8	20	63			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
June 23, 1969

Hour GMT	Position Lat.	Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	14°50'N	55°39'W	0.6	2.5	0.8	24	75			
0100	14°43'	55°30'	0.5	2.5	0.8	20	63			
0200	14°35'	55°20'	0.5	2.5	0.8	20	63			
0300	14°27'	55°12'	0.6	2.6	0.8	23	75			
0400	14°20'	55°03'	0.7	2.6	0.8	27	88	M	M	
0500	14°13'	54°53'	0.5	2.7	0.8	19	63			
0600	14°06'	54°45'	1.0	2.8	0.8	36	125			
0700	13°59'	54°36'	0.7	2.9	1.0	24	70			
0800	13°52'	54°27'	0.7	3.0	1.0	23	70			
0900	13°45'	54°18'	0.8	3.0	1.0	27	80			
1000	13°37'	54°08'	0.7	2.8	1.0	25	70	M	M	
1100	13°30'	54°00'	0.5	2.7	0.8	19	63			
1200	13°31'	53°48'	0.5	2.3	0.8	22	63			
1300	13°31'	53°37'	0.6	2.1	0.8	29	75			
1400	13°31'	53°26'	0.6	2.3	0.8	26	75			
1500	13°31'	53°14'	0.4	2.2	0.8	18	50			
1600	13°31'	53°03'	0.4	2.3	0.8	17	50	1.32	.24	O_x(KI) - 1.1 pphm
1700	13°30'	53°00'	M	M	M	M	M			
1800	13°30'	53°00'	M	M	M	M	M			
1900	13°34'	53°00'	0.6	2.3	0.6	26	100			
2000	13°46'	53°00'	0.5	2.3	0.6	22	83			
2100	13°53'	53°00'	0.5	2.3	0.6	22	83			
2200	14°01'	53°00'	M	M	M	M	M	1.42	.34	
2300	14°02'	53°00'	M	M	M	M	M			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
June 24, 1969

Hour GMT	Position Lat.	Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	14°08'N	53°00'W	0.7	2.5	0.8	28	88			
0100	14°21'	53°00'	0.8	2.5	0.8	32	100			
0200	14°30'	53°00'	M	M	M	M	M			
0300	14°30'	53°00'	M	M	M	M	M			
0400	14°44'	53°00'	0.5	2.3	0.8	22	63	1.41	.18	
0500	15°00'	53°00'	M	M	M	M	M			
0600	15°00'	53°00'	M	M	M	M	M			
0700	15°00'	53°00'	0.7	2.6	0.8	27	88			
0800	15°17'	53°00'	0.6	2.6	0.8	23	75			
0900	15°30'	53°00'	0.6	2.3	0.8	26	75			
1000	15°30'	53°00'	M	M	M	M	M	M	M	
1100	15°36'	53°00'	M	M	M	M	M			
1200	15°47'	53°00'	0.6	2.5	0.8	24	75			
1300	16°00'	53°00'	M	M	M	M	M			
1400	16°00'	53°00'	M	M	M	M	M			
1500	16°05'	53°00'	0.6	2.5	0.6	24	100			$O_x(KI)$ - 1.2 pphm
1600	16°21'	53°00'	0.7	2.5	0.6	28	117	1.39	.15	
1700	16°26'	53°00'	0.6	2.5	0.6	24	100			
1800	16°30'	53°00'	M	M	M	M	M			
1900	16°37'	53°00'	M	M	M	M	M			
2000	16°48'	53°00'	0.7	2.4	0.9	29	78			
2100	17°00'	53°00'	M	M	M	M	M			
2200	17°00'	53°00'	M	M	M	M	M	1.41	.15	
2300	17°03'	53°00'	0.7	2.5	1.4	28	50			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
June 25, 1969

Hour GMT	Position Lat.	Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	17°16'N	53°00'W	0.6	2.5	1.4	24	43			Possible contamination of sample by ship's environment. Relative wind was near zero.
0100	17°28'	53°00'	0.5	2.3	1.4	22	36			
0200	17°30'	53°00'	M	M	M	M	M			
0300	17°30'	52°56'	M	M	M	M	M			
0400	17°30'	53°10'	0.5	M	1.3	M	39	1.40	.16	
0500	17°30'	53°24'	0.3	M	1.3	M	23			
0600	17°30'	53°38'	M	M	1.1	M	M			
0700	17°30'	53°52'	M	M	1.4	M	M			
0800	17°30'	54°06'	M	M	1.3	M	M			
0900	17°30'	54°20'	M	M	1.5	M	M			
1000	17°34'	54°34'	M	M	1.5	M	M	1.37	.15	
1100	17°33'	54°48'	0.5	M	1.6	M	31			
1200	17°33'	55°02'	0.5	2.5	1.7	20	29			
1300	17°32'	55°16'	0.4	2.4	1.8	17	22			
1400	17°32'	55°30'	0.5	2.3	1.8	22	28			
1500	17°32'	55°44'	0.5	2.3	1.7	22	29			
1600	17°30'	55°58'	0.5	2.2	1.6	23	31	1.32	.12	O_x(KI) - 1.2 pphm
1700	17°30'	56°12'	0.6	2.1	1.6	29	38			
1800	17°30'	56°26'	0.5	2.1	1.6	24	31			
1900	17°30'	56°30'	M	M	M	M	M			
2000	17°28'	56°32'	M	M	M	M	M			
2100	17°15'	56°30'	0.7	2.5	1.8	28	39			
2200	17°07'	56°32'	0.7	2.5	1.8	28	39	1.39	.12	
2300	17°00'	56°28'	M	M	M	M	M			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
June 26, 1969

Hour GMT	Position Lat.	Position Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	17°00'N	56°30'W	M	M	M	M	M			
0100	16°47'	56°30'	0.5	2.5	2.0	20	25			Possible contamination by ship's environment. Relative wind was near zero.
0200	16°36'	56°30'	0.5	2.5	1.9	20	26			
0300	16°30'	56°30'	M	M	M	M	M			
0400	16°20'	56°30'	M	M	M	M	M	1.94	1.92	
0500	16°16'	56°30'	0.6	2.8	2.3	21	26			
0600	16°04'	56°30'	0.7	2.7	2.3	26	30			
0700	16°00'	56°30'	M	M	M	M	M			
0800	16°00'	56°32'	M	M	M	M	M			
0900	15°50'	56°33'	0.7	3.0	2.5	23	28			
1000	15°37'	56°33'	0.7	2.8	2.3	25	30	1.40	.13	
1100	15°30'	56°30'	M	M	M	M	M			
1200	15°30'	56°30'	M	M	M	M	M			
1300	15°30'	56°30'	M	M	M	M	M			
1400	15°18'	56°30'	0.6	3.0	2.5	20	24			$O_x(KI)$ - 1.3 pphm
1500	15°06'	56°30'	0.5	2.8	2.3	18	22			
1600	15°00'	56°30'	M	M	M	M	M	1.28	.30	
1700	15°00'	56°30'	M	M	M	M	M			
1800	14°47'	56°32'	0.7	2.7	2.1	26	33			
1900	14°35'	56°30'	0.4	2.6	2.0	15	20			
2000	14°30'	56°30'	M	M	M	M	M			
2100	14°26'	56°33'	M	M	M	M	M			
2200	14°12'	56°33'	0.6	2.8	1.5	21	40	1.36	.20	
2300	14°00'	56°29'	M	M	M	M	M			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
June 27, 1969

Hour GMT	Position Lat.	Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	14°00'N	56°29'W	M	M	M	M	M			
0100	13°56'	56°31'	0.7	2.7	1.9	26	37			
0200	13°42'	56°30'	0.4	2.7	1.8	15	22			
0300	13°30'	56°30'	M	M	M	M	M			
0400	13°30'	56°30'	M	M	M	M	M	1.34	.10	
0500	13°22'	56°30'	M	2.1	1.4	M	M			
0600	13°11'	56°30'	M	2.0	1.4	M	M			
0700	13°00'	56°30'	M	M	M	M	M			
0800	12°59'	56°31'	M	M	M	M	M			
0900	12°58'	56°31'	M	1.8	1.4	M	M			
1000	12°46'	56°31'	M	1.5	1.2	M	M	1.42	.17	
1100	12°33'	56°32'	M	M	M	M	M			
1200	12°30'	56°31'	M	M	M	M	M			
1300	12°25'	56°31'	0.4	1.4	1.2	29	33			$O_x(KI)$ - 1.1 pphm
1400	12°20'	56°31'	0.4	1.3	1.0	31	40			
1500	12°05'	56°31'	0.3	1.3	1.0	23	30			
1600	12°00'	56°30'	M	M	M	M	M	M	M	
1700	11°58'	56°32'	M	M	M	M	M			
1800	11°45'	56°32'	0.3	1.3	0.8	23	38			
1900	11°34'	56°32'	0.3	1.3	0.8	23	38			
2000	11°32'	56°32'	M	M	M	M	M			
2100	11°28'	56°36'	0.3	1.5	0.8	20	38			
2200	11°16'	56°35'	0.3	1.6	0.9	19	33	1.33	.13	
2300	11°02'	56°33'	0.4	1.6	1.0	25	40			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
June 28, 1969

Hour GMT	Position Lat.	Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	11°00'N	56°28'W	M	M	M	M	M			
0100	11°00'	56°28'	M	M	M	M	M			
0200	10°54'	56°28'	0.4	1.8	1.0	22	40			
0300	10°42'	56°30'	0.3	1.7	1.0	18	30			
0400	10°30'	56°30'	M	M	M	M	M	1.40	.11	
0500	10°30'	56°30'	M	M	M	M	M			
0600	10°25'	56°32'	M	1.8	1.0	M	M			
0700	10°11'	56°31'	M	1.8	1.0	M	M			
0800	10°00'	56°30'	M	M	M	M	M			
0900	9°56'	56°29'	M	M	M	M	M			
1000	9°49'	56°30'	M	1.8	M	M	M	M	M	
1100	9°32'	56°30'	M	1.8	1.0	M	M			
1200	9°30'	56°31'	M	M	M	M	M			
1300	9°28'	56°31'	0.4	1.6	0.8	25	50			
1400	9°16'	56°31'	0.4	1.6	0.8	25	50			
1500	9°04'	55°31'	0.3	1.6	0.8	19	38			
1600	9°00'	56°30'	M	M	M	M	M	1.35	.13	
1700	8°56'	56°30'	M	M	M	M	M			
1800	8°44'	56°30'	0.2	1.6	1.0	13	20			
1900	8°30'	56°30'	M	M	M	M	M			
2000	8°30'	56°30'	M	M	M	M	M			
2100	8°19'	56°29'	0.3	1.8	1.0	17	30			
2200	8°7.0	56°30'	0.5	1.9	1.0	26	50	1.32	.14	
2300	8°00'	56°30'	M	M	M	M	M			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
June 29, 1969

Hour GMT	Position Lat.	Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	8°00'N	56°30'W	M	M	M	M	M			
0100	7°47'	56°30'	0.5	2.0	1.2	25	42			
0200	7°35'	56°30'	0.5	2.1	1.2	24	42			
0300	7°30'	56°30'	M	M	M	M	M			
0400	7°24'	56°30'	M	M	M	M	M	1.39	.11	
0500	7°18'	56°31'	M	2.3	1.4	M	M			
0600	7°03'	56°30'	M	M	M	M	M			
0700	6°58'	56°26'	0.4	2.3	M	17	M			
0800	6°51'	56°17'	0.6	2.3	M	26	M			
0900	6°46'	56°05'	0.6	2.3	1.4	26	43			
1000	6°40'	55°53'	0.6	2.3	1.4	26	43	1.30	.16	
1100	6°34'	55°41'	0.6	2.3	1.4	26	43			
1200	6°26'	55°29'	0.5	2.3	1.2	22	42			
1300	6°19'	55°17'	0.5	2.1	1.2	24	42			
1400	5°48'	55°10'	0.5	2.0	1.4	25	36			In Port (Paramaribo, Surinam)
1500	5°48'	55°10'	0.3	2.0	1.3	15	23			
1600	5°48'	55°10'	0.2	1.9	1.4	11	14	M	M	
1700	5°48'	55°10'	0.5	2.0	1.4	25	36			
1800	5°48'	55°10'	0.4	2.0	1.4	20	29			
1900	5°48'	55°10'	0.4	2.1	1.4	19	29			
2000	5°48'	55°10'	0.3	2.0	1.4	15	21			
2100	5°48'	55°10'	0.4	1.9	1.3	21	31			
2200	5°48'	55°10'	0.4	1.9	1.0	21	40	M	M	
2300	5°48'	55°10'	0.3	1.9	1.2	16	25			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
June 30, 1969

Hour GMT	Position Lat.	Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	5°48'	55°10'	0.4	1.6	1.2	25	33			
0100	5°48'	55°10'	0.3	1.9	1.2	16	25			
0200	5°48'	55°10'	0.3	1.7	1.2	18	25			
0300	5°48'	55°10'	0.4	1.7	1.0	24	40			
0400	5°48'	55°10'	0.3	1.8	0.9	17	33	M	M	
0500	5°48'	55°10'	0.2	1.7	0.8	12	25			
0600	5°48'	55°10'	0.3	1.4	0.8	21	37			
0700	5°48'	55°10'	0.3	1.2	0.8	25	37			
0800	5°48'	55°10'	0.1	1.4	0.8	7	13			
0900	5°48'	55°10'	0.2	1.3	0.8	16	25			
1000	5°48'	55°10'	0.2	1.1	0.9	18	22	M	M	
1100	5°48'	55°10'	0.4	1.1	1.1	36	36			
1200	5°48'	55°10'	0.4	1.2	1.2	33	33			
1300	5°48'	55°10'	0.4	1.4	1.1	29	36			
1400	5°48'	55°10'	0.5	1.8	1.0	28	50			
1500	5°48'	55°10'	0.4	1.8	1.0	22	40			
1600	5°48'	55°10'	0.1	1.7	1.0	6	10	M	M	
1700	5°48'	55°10'	0.3	1.8	1.0	17	30			
1800	5°48'	55°10'	0.3	1.7	1.1	18	27			
1900	5°48'	55°10'	0.4	1.6	1.2	25	33			
2000	5°48'	55°10'	0.6	1.7	1.3	35	46			
2100	5°48'	55°10'	0.5	1.6	1.4	31	36			
2200	5°48'	55°10'	0.6	1.7	1.3	35	46	M	M	
2300	5°48'	55°10'	0.6	1.7	1.0	35	60			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
July 1, 1969

Hour GMT	Position Lat.	Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	5°48'N	55°10'W	0.3	1.9	1.0	16	30			
0100	5°48'	55°10'	0.5	2.0	1.0	25	50			
0200	5°48'	55°10'	0.5	1.7	1.0	29	50			
0300	5°48'	55°10'	0.4	1.4	0.8	29	50			
0400	5°48'	55°10'	0.3	1.6	0.8	19	38	M	M	
0500	5°48'	55°10'	0.5	1.7	0.7	29	71			
0600	5°48'	55°10'	0.3	1.6	0.6	19	50			
0700	5°48'	55°10'	0.1	1.3	0.6	8	17			
0800	5°48'	55°10'	0.3	1.4	0.6	21	50			
0900	5°48'	55°10'	0.2	1.1	0.4	18	50			
1000	5°48'	55°10'	0.1	0.9	0.5	11	20	M	M	
1100	5°48'	55°10'	0.2	1.2	0.7	17	29			
1200	5°48'	55°10'	0.2	1.5	1.0	13	50			
1300	5°48'	55°10'	0.4	1.7	1.0	24	40			
1400	5°48'	55°10'	0.5	1.7	1.1	29	45			
1500	5°48'	55°10'	0.6	1.8	0.8	33	75			
1600	5°48'	55°10'	0.3	1.7	0.8	18	38	M	M	
1700	5°48'	55°10'	0.5	1.7	0.9	29	56			
1800	5°48'	55°10'	0.2	1.8	1.0	11	20			
1900	5°48'	55°10'	0.3	1.8	0.9	17	33			
2000	5°48'	55°10'	0.5	1.8	0.9	28	56			
2100	5°48'	55°10'	0.4	1.8	0.8	22	50			
2200	5°48'	55°10'	0.2	1.8	0.8	11	25	M	M	
2300	5°48'	55°10'	0.5	1.8	0.8	28	63			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
July 2, 1969

Hour GMT	Position Lat.	Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	5°48'N	55°10'W	0.3	1.5	0.8	20	38			
0100	5°48'	55°10'	0.3	1.3	0.6	23	50			
0200	5°48'	55°10'	0.3	1.3	0.6	23	50			
0300	5°48'	55°10'	0.4	1.3	0.6	31	67			
0400	5°48'	55°10'	0.1	1.1	0.6	9	17	M	M	
0500	5°48'	55°10'	0.3	1.1	0.6	27	50			
0600	5°48'	55°10'	M	1.0	0.6	M	M			
0700	5°48'	55°10'	M	1.0	0.6	M	M			
0800	5°48'	55°10'	M	1.1	0.6	M	M			
0900	5°48'	55°10'	M	1.3	0.6	M	M			
1000	5°48'	55°10'	M	1.3	0.6	M	M	M	M	
1100	5°48'	55°10'	M	1.4	0.6	M	M			
1200	5°48'	55°10'	M	1.5	0.8	M	M			
1300	5°48'	55°10'	0.2	1.5	0.6	13	33			
1400	5°48'	55°10'	0.4	1.5	0.4	27	100			
1500	5°48'	55°10'	0.3	1.6	0.5	19	60			
1600	5°48'	55°10'	0.2	1.6	0.4	13	50	M	M	
1700	5°48'	55°10'	0.9	1.6	0.7	56	129			
1800	5°48'	55°10'	0.8	1.7	0.8	47	100			
1900	5°48'	55°10'	1.1	1.9	1.1	58	100			
2000	5°48'	55°10'	0.6	2.0	1.2	30	50			
2100	6°12'	55°08'	0.5	2.0	1.2	25	42			Last Measurement In Port(Paramaribo, Surinam)
2200	6°20'	54°57'	0.6	2.0	1.2	30	50	M	M	
2300	6°27'	54°47'	1.1	2.0	1.2	55	92			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
July 3, 1969

Hour GMT	Position Lat.	Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	6°34'N	54°35'W	0.5	2.1	1.3	24	38			
0100	6°40'	54°28'	0.5	2.2	1.3	23	38			
0200	6°45'	54°16'	0.7	2.0	1.2	35	58			
0300	6°51'	54°04'	M	M	M	M	M			
0400	6°49'	54°10'	0.5	2.1	1.3	24	38	1.42	.11	
0500	7°01'	53°54'	0.9	2.2	1.3	41	69			
0600	7°20'	53°48'	0.8	2.3	1.5	35	53			
0700	7°26'	53°38'	0.3	2.1	1.4	14	21			
0800	7°33'	53°31'	0.7	2.1	1.4	33	50			
0900	7°40'	53°25'	M	M	M	M	M			
1000	7°40'	53°25'	M	M	M	M	M	1.34	.10	
1100	7°49'	53°15'	0.7	2.1	1.3	33	54			
1200	8°06'	53°08'	M	2.4	1.6	M	M			
1300	8°14'	52°57'	M	2.5	1.6	M	M			$O_x(KI)$ - 1.1 pphm
1400	8°17'	52°40'	M	M	M	M	M			
1500	8°17'	52°40'	M	M	M	M	M			
1600	8°20'	52°39'	0.2	2.1	1.2	10	17	1.38	.12	
1700	8°28'	52°27'	1.0	2.1	1.2	48	83			
1800	8°37'	52°19'	1.8	2.1	1.2	86	150			
1900	8°44'	52°09'	M	2.1	1.2	M	M			
2000	8°52'	52°02'	0.1	2.1	1.4	5	7			
2100	9°00'	51°56'	M	M	M	M	M			
2200	9°00'	51°56'	M	M	M	M	M	1.38	.21	
2300	9°00'	51°43'	0.4	2.1	1.2	19	33			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
July 4, 1969

Hour GMT	Position Lat.	Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	9°19'N	51°29'W	0.7	2.1	1.2	33	58			
0100	9°24'	51°20'	0.6	2.1	1.2	29	50			
0200	9°30'	51°10'	M	M	M	M	M			
0300	9°30'	51°10'	M	M	M	M	M			
0400	9°44'	51°07'	M	2.1	1.2	M	M	1.43	.12	
0500	9°50'	50°54'	M	2.1	1.2	M	M			
0600	9°54'	50°42'	M	2.6	1.8	M	M			
0700	10°00'	50°30'	M	2.2	1.5	M	M			
0800	10°06'	50°20'	M	2.2	1.4	M	M			
0900	10°12'	50°15'	0.8	2.3	1.4	35	57			
1000	10°15'	50°05'	M	M	M	M	M	1.39	.13	
1100	10°20'	50°01'	0.2	2.2	1.4	9	14			
1200	10°34'	49°56'	0.7	2.3	1.4	30	50			
1300	10°41'	49°49'	0.7	2.3	1.4	30	50			
1400	10°51'	49°38'	0.3	2.5	1.5	12	20			$O_x(KI)$ - 1.1 pphm
1500	11°00'	49°45'	M	M	M	M	M			
1600	11°00'	49°45'	M	M	M	M	M	M	M	
1700	10°45'	49°40'	0.5	2.3	1.2	22	42			
1800	10°35'	49°45'	0.4	2.1	1.2	19	33			
1900	10°30'	49°50'	M	M	M	M	M			
2000	10°30'	49°50'	M	M	M	M	M			
2100	10°25'	49°50'	1.8	2.3	1.2	78	150			
2200	10°13'	49°53'	1.4	2.2	1.2	64	117	1.33	.13	
2300	10°00'	49°55'	M	M	M	M	M			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
July 5, 1969

Hour GMT	Position Lat.	Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	10°00'N	49°55'W	M	M	M	M	M			
0100	10°00'	49°55'	M	M	M	M	M			
0200	9°44'	49°59'	M	2.4	1.2	M	M			
0300	9°31'	50°18'	M	2.5	1.2	M	M			
0400	9°30'	50°16'	M	M	M	M	M	1.33	.12	
0500	9°31'	50°22'	M	2.5	1.2	M	M			
0600	9°18'	50°24'	M	2.4	1.2	M	M			
0700	9°05'	50°26'	M	2.3	1.2	M	M			
0800	9°00'	50°30'	M	M	M	M	M			
0900	8°57'	50°43'	M	2.3	1.2	M	M			
1000	8°45'	50°39'	0.8	2.1	1.2	38	67	1.34	.15	
1100	8°35'	50°43'	0.8	2.1	1.2	38	67			
1200	8°30'	50°45'	M	M	M	M	M			
1300	8°25'	50°44'	0.4	2.0	1.2	20	33			
1400	8°16'	50°51'	0.5	2.0	1.1	25	45			$O_x(KI)$ - 1.1 pphm
1500	8°05'	50°57'	0.5	2.0	1.0	25	50			
1600	8°00'	51°00'	M	M	M	M	M	1.36	.12	
1700	7°50'	51°02'	0.5	1.8	0.8	28	63			
1800	7°40'	51°08'	0.4	1.9	0.8	21	50			
1900	7°22'	51°10'	M	M	M	M	M			
2000	7°20'	51°12'	1.0	2.1	0.9	48	111			
2100	7°14'	51°14'	0.4	2.1	1.0	18	40			
2200	7°08'	51°23'	M	M	M	M	M	1.35	.12	
2300	7°08'	51°23'	M	M	M	M	M			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
July 6, 1969

Hour GMT	Position Lat.	Position Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	6°55'N	51°29'W	0.6	2.0	1.0	30	60			
0100	6°40'	51°36'	0.5	2.0	1.0	25	50			
0200	6°40'	51°36'	M	M	M	M	M			
0300	6°34'	51°39'	0.6	1.8	1.0	33	60			
0400	6°23'	51°44'	0.5	1.8	1.0	28	50	1.36	.14	
0500	6°12'	51°48'	M	M	M	M	M			
0600	6°12'	51°48'	M	M	M	M	M			
0700	6°07'	51°43'	0.5	1.6	1.0	31	50			
0800	5°54'	51°29'	0.5	1.6	0.8	31	63			
0900	5°42'	51°17'	0.4	1.6	0.8	25	50			
1000	5°34'	51°09'	0.4	1.6	0.8	25	50	1.34	.10	
1100	5°25'	50°59'	0.3	1.6	0.8	19	38			
1200	5°14'	50°49'	0.4	1.6	0.8	25	50			
1300	5°05'	50°41'	1.1	1.6	0.8	69	138			O_x(KI) - 1.2 pphm
1400	4°58'	50°34'	0.3	0.5	0.7	60	43			New calibration value
1500	4°49'	50°25'	0.5	0.6	0.7	83	71			used for oxidant and ozone.
1600	4°46'	50°20'	0.4	0.5	0.7	80	57	1.36	.08	
1700	4°39'	50°13'	0.4	0.4	0.7	100	57			
1800	4°29'	50°03'	0.4	0.4	0.7	100	57			
1900	4°23'	49°56'	M	M	M	M	M			
2000	4°19'	49°54'	M	0.4	0.7	M	M			
2100	4°11'	49°46'	0.5	0.5	0.7	100	71			
2200	4°05'	49°37'	0.4	0.5	0.7	80	57	1.30	.11	
2300	3°47'	49°29'	0.4	0.5	0.7	80	57			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
July 7, 1969

Hour GMT	Position Lat.	Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	3°48'N	49°21'W	0.6	0.5	0.7	120	86			
0100	3°41'	49°12'	0.9	0.5	0.7	180	129			
0200	3°33'	49°03'	0.6	0.5	0.7	120	86			
0300	3°25'	48°55'	0.5	0.5	0.7	100	71			
0400	3°18'	48°44'	0.7	0.5	0.7	140	100	1.36	.12	
0500	3°10'	48°37'	0.3	0.6	0.8	50	38			
0600	3°03'	48°28'	0.6	0.7	0.9	86	67			
0700	2°55'	48°19'	0.7	0.7	0.9	100	78			
0800	2°47'	48°11'	0.4	0.7	0.9	57	44			
0900	2°39'	48°11'	0.6	0.7	0.9	86	67			
1000	2°32'	48°03'	0.5	0.7	0.9	71	56	1.40	.11	
1100	2°27'	47°53'	0.5	0.7	1.1	71	45			
1200	2°21'	47°44'	M	M	M	M	M			
1300	2°18'	47°35'	0.5	0.5	1.1	100	45			
1400	2°13'	47°25'	0.9	0.7	1.2	129	75			
1500	2°05'	47°18'	0.5	0.7	1.3	71	38			$O_x(KI)$ - 1.1 pphm
1600	1°57'	47°21'	0.4	0.6	1.2	67	33	M	M	
1700	1°45'	47°26'	0.5	0.5	1.0	100	50			
1800	1°33'	47°23'	0.6	0.6	1.0	100	60			
1900	1°23'	47°23'	0.4	0.6	0.9	67	44			
2000	1°11'	47°22'	0.8	0.7	1.1	114	73			
2100	1°00'	47°23'	1.0	0.7	1.1	143	91			
2200	0°46'	47°23'	M	0.7	1.1	M	M	1.34	.07	
2300	0°30'	47°21'	0.7	0.8	1.1	88	64			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
July 8, 1969

Hour GMT	Position Lat.	Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	0°14'N	47°21'W	0.5	0.7	0.9	71	56			
0100	0°00'	47°21'	0.6	0.7	0.9	86	67			
0200	0°01'	47°21'	M	M	M	M	M			
0300	0°06'	47°21'	0.9	0.7	1.1	129	82			
0400	0°02'	47°31'	0.8	0.7	1.1	114	73	1.28	.08	
0500	0°04'	47°37'	0.4	0.7	1.1	57	36			
0600	0°16'	47°47'	0.7	0.7	1.1	100	64			
0700	0°28'	47°55'	0.8	0.7	1.1	114	73			
0800	0°42'	48°06'	0.6	0.7	1.1	86	55			
0900	0°48'	48°09'	0.9	0.7	1.1	129	82			
1000	1°00'	48°16'	0.7	0.7	1.1	100	64	1.29	.10	
1100	1°13'	48°22'	0.5	0.7	1.1	71	45			
1200	1°25'	48°29'	1.3	0.7	1.1	186	118			
1300	1°36'	48°38'	0.6	0.6	1.0	100	60			
1400	1°51'	48°40'	M	0.6	0.9	M	M			
1500	2°00'	48°51'	M	0.6	0.7	M	M			
1600	2°16'	49°10'	M	0.5	0.6	M	M	1.49	.10	
1700	2°25'	49°21'	M	0.5	0.7	M	M			
1800	2°35'	49°31'	0.1	0.5	0.7	20	14			
1900	2°45'	49°37'	0.5	0.5	0.7	100	71			
2000	2°54'	49°48'	M	0.5	0.7	M	M			
2100	3°04'	49°59'	0.5	0.5	0.9	100	56			
2200	3°14'	50°09'	M	0.5	0.9	M	M	1.34	.06	
2300	3°23'	50°20'	M	0.5	0.9	M	M			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
July 9, 1969

Hour GMT	Position Lat.	Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	3°36'N	50°28'W	0.5	0.5	0.9	100	56			
0100	3°48'	50°36'	0.5	0.6	0.9	83	56			
0200	4°00'	50°43'	0.5	0.7	0.9	71	56			
0300	4°12'	50°51'	0.6	0.7	0.9	86	67			
0400	4°24'	50°59'	0.6	0.7	0.9	86	67	1.35	.11	
0500	4°33'	51°10'	0.1	0.7	0.9	14	11			
0600	4°43'	51°22'	0.0	0.7	0.9	0	0			
0700	4°52'	51°34'	0.2	0.7	0.9	29	22			
0800	5°01'	51°47'	0.1	0.7	0.9	14	11			
0900	5°10'	51°58'	0.0	0.7	0.9	0	0			
1000	5°19'	52°11'	0.2	0.7	0.9	29	22	1.40	.08	
1100	5°28'	52°22'	0.3	0.7	0.9	43	33			
1200	5°37'	52°21'	0.6	0.7	0.9	86	67			
1300	5°41'	52°33'	0.5	0.6	0.8	83	63			
1400	5°45'	52°45'	0.4	0.6	0.7	67	57			
1500	5°48'	52°57'	0.4	0.6	0.7	67	57			
1600	5°52'	53°10'	0.4	0.5	0.6	80	67	1.40	.11	
1700	5°55'	53°22'	0.2	0.4	0.6	50	33			
1800	6°00'	53°38'	0.4	0.4	0.7	100	57			
1900	6°03'	53°53'	0.3	0.4	0.7	75	43			
2000	6°07'	54°08'	0.6	0.5	0.7	120	86			
2100	6°12'	54°23'	0.5	0.5	0.7	100	71			
2200	6°12'	54°35'	0.5	0.6	0.7	83	71	1.36	.10	
2300	6°12'	54°48'	0.7	0.6	0.9	117	78			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
July 10, 1969

Hour GMT	Position Lat.	Position Long.	$O_3(R)$ pphm	$O_X(M_1)$ pphm	$O_X(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	6°12'	55°00'	0.5	0.7	0.9	71	56			
0100	6°14'	55°16'	0.5	0.7	0.9	71	56			
0200	6°22'	55°27'	0.6	0.7	0.9	86	67			
0300	6°30'	55°39'	0.5	0.6	1.0	83	50			
0400	6°37'	55°49'	0.7	0.6	0.9	117	78	1.32	.10	
0500	6°44'	56°00'	0.7	0.6	0.9	117	78			
0600	6°54'	56°14'	M	0.7	1.0	M	M			
0700	7°02'	56°25'	M	0.7	1.2	M	M			
0800	7°10'	56°37'	M	0.7	1.3	M	M			
0900	7°15'	56°47'	M	0.7	1.1	M	M			
1000	7°21'	56°58'	M	0.6	1.1	M	M	1.33	.10	
1100	7°29'	57'09'	M	0.6	1.1	M	M			
1200	7°39'	57°20'	M	0.6	1.2	M	M			
1300	7°46'	57°31'	M	0.6	1.1	M	M			
1400	7°54'	57°43'	M	0.6	1.1	M	M			
1500	7°06'	57°54'	M	0.6	1.1	M	M			
1600	8°07'	58°04'	M	0.6	1.1	M	M	1.28	.30	
1700	8°14'	58°15'	M	0.6	1.3	M	M			
1800	8°22'	58°27'	M	0.6	1.2	M	M			
1900	8°30'	58°38'	M	0.8	0.9	M	M			
2000	8°37'	58°49'	M	0.6	0.9	M	M			
2100	8°45'	59°01'	M	0.6	0.9	M	M			
2200	8°56'	59°12'	M	0.5	0.9	M	M	1.31	.08	
2300	9°01'	59°24'	M	0.6	0.9	M	M			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
July 11, 1969

Hour GMT	Position Lat.	Position Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	9°11'	59°34'	M	0.5	0.9	M	M			
0100	9°18'	59°46'	M	0.6	0.9	M	M			
0200	9°26'	59°58'	M	0.6	0.9	M	M			
0300	9°35'	60°09'	M	0.5	0.8	M	M			
0400	9°45'	60°23'	M	0.4	0.7	M	M	1.28	.34	
0500	9°55'	60°36'	M	0.4	0.7	M	M			
0600	10°07'	60°49'	M	0.4	0.7	M	M			
0700	10°21'	60°48'	M	0.4	0.7	M	M			
0800	10°39'	60°48'	M	0.4	0.7	M	M			
0900	10°54'	60°49'	M	0.3	0.7	M	M			
1000	10°55'	61°01'	M	0.3	0.7	M	M	M	M	
1100	10°53'	61°19'	M	0.2	0.7	M	M			
1200	10°47'	61°36'	M	0.3	0.6	M	M			
1300	10°45'	61°45'	M	0.4	0.6	M	M			
1400	10°45'	61°45'	M	0.6	0.9	M	M			
1500	10°45'	61°45'	M	0.8	1.3	M	M			
1600	10°44'	61°45'	M	0.8	1.6	M	M	M	M	In Port(Port-of-Spain, Trinidad)
1700	10°44'	61°45'	M	0.6	0.9	M	M			
1800	10°44'	61°45'	M	0.6	0.9	M	M			
1900	10°44'	61°45'	M	0.4	0.7	M	M			
2000	10°44'	61°45'	M	0.3	0.6	M	M			
2100	10°44'	61°45'	M	0.2	0.6	M	M			
2200	10°44'	61°45'	M	0.0	0.4	M	M	M	M	
2300	10°44'	61°45'	M	0.0	0.4	M	M			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
July 12, 1969

Hour GMT	Position Lat.	Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	10°44'N	61°45'W	M	0.0	0.2	M	M			
0100	10°44'	61°45'	M	0.0	0.2	M	M			
0200	10°44'	61°45'	M	0.0	0.2	M	M			
0300	10°44'	61°45'	M	0.0	0.2	M	M			
0400	10°44'	61°45'	M	0.0	0.2	M	M	M	M	
0500	10°44'	61°45'	M	0.0	0.2	M	M			
0600	10°44'	61°45'	M	0.0	0.2	M	M			
0700	10°44'	61°45'	M	0.0	0.2	M	M			
0800	10°44'	61°45'	M	0.0	0.2	M	M			
0900	10°44'	61°45'	M	0.0	0.2	M	M			
1000	10°44'	61°45'	M	0.0	0.3	M	M	M	M	
1100	10°44'	61°45'	M	0.1	0.3	M	M			
1200	10°44'	61°45'	M	0.2	0.4	M	M			
1300	10°44'	61°45'	M	0.3	0.2	M	M			
1400	10°44'	61°45'	M	0.5	0.3	M	M			
1500	10°44'	61°45'	M	M	0.6	M	M			
1600	10°44'	61°45'	M	M	0.7	M	M	M	M	
1700	10°44'	61°45'	M	0.5	0.5	M	M			
1800	10°44'	61°45'	M	0.5	0.4	M	M			
1900	10°44'	61°45'	M	0.5	0.4	M	M			
2000	10°44'	61°45'	M	0.3	0.3	M	M			
2100	10°44'	61°45'	M	0.2	0.2	M	M			
2200	10°44'	61°45'	M	0.0	0.2	M	M	M	M	
2300	10°44'	61°45'	M	0.0	0.2	M	M			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
July 13, 1969

Hour GMT	Position Lat.	Position Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	10°44'N	61°45'W	M	0.0	0.2	M	M			
0100	10°44'	61°45'	M	0.0	0.2	M	M			
0200	10°44'	61°45'	M	0.0	0.2	M	M			
0300	10°44'	61°45'	M	0.0	0.2	M	M			
0400	10°44'	61°45'	M	0.0	0.2	M	M	M	M	
0500	10°44'	61°45'	M	0.0	0.2	M	M			
0600	10°44'	61°45'	M	0.0	0.2	M	M			
0700	10°44'	61°45'	M	0.0	0.2	M	M			
0800	10°44'	61°45'	M	0.0	0.2	M	M			
0900	10°44'	61°45'	M	0.0	0.2	M	M			
1000	10°44'	61°45'	M	0.0	0.2	M	M	M	M	
1100	10°44'	61°45'	M	0.0	0.2	M	M			
1200	10°44'	61°45'	M	0.1	0.5	M	M			
1300	10°44'	61°45'	M	0.4	0.4	M	M			
1400	10°44'	61°45'	M	0.5	0.3	M	M			
1500	10°44'	61°45'	M	0.3	0.4	M	M			
1600	10°44'	61°45'	M	0.3	0.4	M	M	M	M	
1700	10°44'	61°45'	M	0.3	0.5	M	M			
1800	10°44'	61°45'	M	0.4	0.4	M	M			
1900	10°44'	61°45'	M	0.4	0.4	M	M			
2000	10°44'	61°45'	M	0.3	0.4	M	M			
2100	10°44'	61°45'	M	0.3	0.3	M	M			
2200	10°44'	61°45'	M	0.3	0.2	M	M	M	M	
2300	10°44'	61°45'	M	0.1	0.2	M	M			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
July 14, 1969

Hour GMT	Position Lat.	Position Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	10°44'N	61°45'W	M	0.1	0.2	M	M			
0100	10°44'	61°45'	M	0.0	0.2	M	M			
0200	10°44'	61°45'	M	0.0	0.2	M	M			
0300	10°44'	61°45'	M	0.0	0.2	M	M			
0400	10°44'	61°45'	M	0.0	0.2	M	M	M	M	
0500	10°44'	61°45'	M	0.0	0.2	M	M			
0600	10°44'	61°45'	M	0.0	0.2	M	M			
0700	10°44'	61°45'	M	0.0	0.2	M	M			
0800	10°44'	61°45'	M	0.0	0.2	M	M			
0900	10°44'	61°45'	M	0.0	0.2	M	M			
1000	10°44'	61°45'	M	0.0	0.2	M	M	M	M	
1100	10°44'	61°45'	M	0.2	0.2	M	M			
1200	10°44'	61°45'	M	0.2	0.2	M	M			
1300	10°44'	61°45'	M	0.4	0.3	M	M			
1400	10°44'	61°45'	M	0.5	0.4	M	M			
1500	10°44'	61°45'	M	0.4	0.4	M	M			
1600	10°44'	61°45'	M	0.5	0.9	M	M	M	M	
1700	10°44'	61°45'	M	0.6	1.0	M	M			
1800	10°44'	61°45'	0.0	0.6	0.9	0.0	0.0			
1900	10°44'	61°45'	0.1	0.6	0.9	17	11			Last Measurement In Port(Port-of-Spain, Trinidad)
2000	10°56'	61°54'	0.2	0.5	0.9	40	22			
2100	11°08'	62°01'	0.6	0.5	0.9	120	67			
2200	11°21'	62°08'	0.4	0.5	0.9	80	44	1.40	.21	
2300	11°33'	62°16'	0.3	0.5	0.9	60	33			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
July 15, 1969

Hour GMT	Position Lat.	Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	11°45'N	62°22'W	0.6	0.5	0.9	120	67			
0100	11°57'	62°29'	0.5	0.5	0.9	100	56			
0200	12°10'	62°35'	0.5	0.5	1.1	100	46			
0300	12°20'	62°40'	0.4	0.6	1.1	67	37			
0400	12°34'	62°46'	0.5	0.7	1.1	71	46	1.35	.11	
0500	12°47'	62°51'	0.7	0.7	1.3	100	54			
0600	13°00'	62°58'	0.6	0.7	1.3	86	46			
0700	13°13'	63°08'	0.5	0.7	1.1	71	46			
0800	13°26'	63°09'	0.6	0.6	1.2	100	50			
0900	13°47'	63°19'	0.6	0.6	1.3	100	46			
1000	14°00'	63°25'	0.6	0.7	1.2	86	50	1.42	.24	
1100	14°13'	63°31'	0.5	0.6	1.3	83	38			
1200	14°27'	63°36'	0.5	0.6	1.5	83	33			
1300	14°40'	63°44'	0.6	0.7	2.0	86	30			
1400	14°54'	63°50'	0.6	0.8	1.8	75	33			
1500	15°01'	63°53'	0.7	0.9	1.5	78	47			O_x(KI) - 1.1 pphm
1600	15°06'	63°59'	1.0	M	1.6	M	63	M	M	
1700	15°22'	64°19'	0.3	M	1.7	M	17			
1800	15°30'	64°29'	0.6	0.8	1.7	75	35			
1900	15°38'	64°40'	0.6	0.8	2.0	75	30			
2000	15°46'	64°50'	0.8	0.9	M	89	M			
2100	15°54'	65°01'	0.7	M	M	M	M			
2200	16°02'	65°11'	0.8	M	2.2	M	37	1.42	.19	
2300	16°10'	65°21'	1.0	1.1	2.4	91	42			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
July 16, 1969

Hour GMT	Position Lat.	Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	16°19'N	65°32'W	0.7	1.1	2.3	64	30			
0100	16°26'	65°42'	0.9	1.1	2.2	82	41			
0200	16°34'	65°52'	1.3	1.0	2.2	130	59			
0300	16°42'	66°02'	0.9	1.0	2.1	90	43			
0400	16°50'	66°12'	0.9	1.0	2.2	90	41	1.36	.08	
0500	16°58'	66°23'	0.8	1.0	2.1	80	38			
0600	17°06'	66°34'	1.0	1.0	2.2	100	46			
0700	17°14'	66°44'	0.9	1.0	2.2	90	41			
0800	17°22'	66°55'	1.0	1.1	2.3	91	44			
0900	17°47'	67°08'	1.1	1.1	2.2	100	50			
1000	17°54'	67°20'	1.1	1.0	1.8	110	61	1.34	.12	
1100	18°00'	67°34'	0.8	0.9	1.8	89	44			
1200	18°08'	67°43'	0.5	0.8	1.7	63	29			
1300	18°17'	67°53'	M	1.0	1.9	M	M			
1400	18°29'	68°00'	0.8	1.2	M	M	M			$O_x(KI)$ - 0.5 pphm. New calibration value used for oxidant and ozone.
1500	18°41'	68°13'	0.6	M	M	M	M			
1600	18°54'	68°14'	0.4	0.8	M	50	M	1.32	.29	
1700	19°06'	68°21'	0.3	0.6	M	50	M			
1800	19°18'	68°29'	0.3	0.5	M	60	M			
1900	19°29'	68°36'	0.5	0.5	M	100	M			
2000	19°41'	68°43'	0.5	0.5	0.5	100	100			
2100	19°54'	68°51'	0.5	0.5	0.5	100	100			
2200	20°06'	68°58'	0.5	0.5	0.5	100	100	1.36	.24	
2300	20°18'	69°05'	0.6	0.5	0.5	120	100			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
July 17, 1969

Hour GMT	Position Lat.	Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	20°31'N	69°13'W	0.3	0.5	0.5	60	60			
0100	20°41'	69°18'	0.7	0.5	0.5	140	140			
0200	20°49'	69°29'	0.4	0.5	0.5	80	80			
0300	20°57'	69°41'	0.4	0.5	0.5	80	80			
0400	21°06'	69°52'	0.6	0.6	0.5	100	120	1.32	.20	
0500	21°12'	69°52'	0.5	0.6	0.5	83	100			
0600	21°19'	70°04'	0.5	0.6	0.5	83	100			
0700	21°26'	70°15'	0.4	0.6	0.7	67	57			
0800	21°32'	70°39'	0.5	0.6	0.6	83	83			
0900	21°38'	70°50'	0.5	0.6	0.5	83	100			
1000	21°49'	70°59'	0.5	0.6	0.5	83	100	M	M	
1100	21°51'	71°39'	0.8	0.6	0.7	133	114			
1200	22°13'	71°19'	0.6	0.6	0.7	100	86			
1300	22°21'	71°30'	0.3	0.7	0.7	43	43			$O_x(KI)$ - 0.9 pphm
1400	22°29'	71°44'	0.5	0.8	0.7	63	71			
1500	22°37'	71°56'	1.0	0.8	0.7	125	143			
1600	22°46'	72°09'	0.4	0.8	0.7	50	57	1.44	.11	
1700	22°53'	72°20'	0.4	0.8	0.7	50	57			
1800	23°00'	72°31'	0.6	0.8	0.8	75	75			
1900	23°08'	72°43'	0.8	0.8	0.7	100	114			
2000	23°16'	72°56'	0.5	0.8	0.8	63	63			
2100	23°23'	73°09'	0.7	0.8	0.8	88	88			
2200	23°32'	73°21'	0.6	0.8	0.8	75	75	1.40	.27	
2300	23°40'	73°37'	0.7	0.8	0.9	88	78			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
July 18, 1969

Hour GMT	Position Lat.	Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	23°48'N	73°44'W	0.5	0.9	1.0	56	50			
0100	23°58'	73°56'	0.6	0.9	1.0	67	60			
0200	24°06'	74°09'	0.7	0.9	1.0	78	70			
0300	24°14'	74°20'	0.7	1.0	1.0	70	70			
0400	24°23'	74°32'	M	1.0	1.1	M	M	M	M	
0500	24°31'	74°43'	M	1.0	1.1	M	M			
0600	24°38'	74°54'	M	1.1	1.1	M	M			
0700	24°47'	75°06'	M	1.1	1.2	M	M			
0800	24°56'	75°15'	0.7	1.2	1.2	58	58			
0900	25°04'	75°30'	0.7	1.2	1.2	58	58			
1000	25°15'	75°41'	0.5	1.1	1.2	45	42	M	M	
1100	25°23'	75°52'	1.3	1.3	1.3	100	100			
1200	25°28'	76°07'	0.7	1.1	M	64	M			
1300	25°32'	76°23'	0.7	1.1	M	64	M			O_x(KI) - 2.0 pphm
1400	25°35'	76°37'	0.6	M	M	M	M			
1500	25°34'	76°49'	0.5	M	M	M	M			
1600	25°33'	77°01'	1.4	M	M	M	M	M	M	In Port (Nassau)
1700	25°04'	77°20'	1.0	M	M	M	M			
1800	25°04'	77°20'	0.8	M	M	M	M			
1900	25°04'	77°20'	0.4	M	M	M	M			
2000	25°04'	77°20'	0.4	M	M	M	M			
2100	25°04'	77°20'	0.4	M	0.1	M	4			
2200	25°04'	77°20'	0.6	M	0.5	M	120	M	M	
2300	25°04'	77°20'	0.4	M	0.7	M	57			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
July 19, 1969

Hour GMT	Position Lat.	Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	25°04'N	77°20'W	0.5	1.3	1.0	38	50			
0100	25°04'	77°20'	0.6	1.2	1.0	50	60			
0200	25°04'	77°20'	1.1	1.1	1.2	100	92			
0300	25°04'	77°20'	0.9	1.4	1.1	64	82			
0400	25°04'	77°20'	1.0	1.2	0.8	83	125	M	M	
0500	25°04'	77°20'	0.9	1.0	1.0	90	90			
0600	25°04'	77°20'	0.8	1.5	1.2	53	67			
0700	25°04'	77°20'	1.0	1.5	1.1	67	91			
0800	25°04'	77°20'	0.9	1.4	1.2	64	75			
0900	25°04'	77°20'	0.7	1.3	1.1	54	64			
1000	25°04'	77°20'	0.8	1.3	1.0	62	80	M	M	
1100	25°04'	77°20'	M	0.9	0.5	M	M			
1200	25°04'	77°20'	0.3	0.8	0.7	38	43			
1300	25°04'	77°20'	0.3	1.1	1.0	27	30			
1400	25°04'	77°20'	0.4	1.1	0.9	36	44			O_x(KI) - 1.4 pphm
1500	25°04'	77°20'	M	1.1	0.6	M	M			Last Measurement In Port (Nassau)
1600	25°11'	77°25'	M	M	0.7	M	M	M	M	
1700	25°12'	77°25'	0.5	1.0	0.9	50	56			
1800	25°25'	77°32'	0.4	1.1	1.0	36	40			
1900	25°35'	77°37'	0.5	1.1	1.0	46	50			
2000	25°48'	77°45'	0.7	1.2	1.0	58	70			
2100	25°56'	77°57'	0.9	1.2	1.0	75	90			
2200	26°03'	78°08'	1.0	1.3	1.0	77	100	1.38	.06	
2300	26°10'	78°19'	0.8	1.3	1.0	62	80			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
July 20, 1969

Hour GMT	Position Lat.	Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	26°20'	78°36'	0.8	1.3	1.0	62	80			
0100	26°26'	78°51'	0.7	1.3	1.0	54	70			
0200	26°32'	79°06'	0.8	1.3	1.0	62	80			
0300	26°41'	79°17'	0.8	1.2	1.0	67	80			
0400	26°53'	79°27'	0.7	1.2	1.0	58	70	1.40	.10	
0500	27°04'	79°36'	0.8	1.4	1.0	57	80			
0600	27°20'	79°36'	0.9	1.3	0.8	69	113			
0700	27°39'	79°41'	0.9	1.2	0.8	75	113			
0800	27°53'	79°37'	0.9	1.2	0.8	75	113			
0900	28°10'	79°38'	1.1	1.2	0.8	92	138			
1000	28°29'	79°40'	0.6	1.2	0.8	50	75	1.31	.09	
1100	28°46'	79°40'	0.9	1.2	0.8	75	113			
1200	29°02'	79°40'	0.7	M	0.8	M	88			
1300	29°20'	79°38'	1.0	M	0.9	M	111			O_x(KI) - 0.8 pphm
1400	29°36'	79°38'	1.1	M	1.0	M	110			
1500	29°51'	79°38'	0.9	M	1.1	M	82			
1600	30°07'	79°38'	0.8	M	0 9	M	89	1.43	.11	
1700	30°21'	79°35'	1.2	M	0.8	M	150			
1800	30°36'	79°33'	0.9	M	0.8	M	113			
1900	30°51'	79°25'	0.7	M	0.8	M	88			
2000	31°05'	79°19'	0.5	M	0.7	M	71			
2100	31°21'	79°13'	0.7	M	0.8	M	88			
2200	31°35'	79°05'	1.0	M	0.7	M	143	M	M	
2300	31°53'	78°56'	0.9	M	0.8	M	113			

Atmospheric Trace Gas Concentrations
S. S. ADVANCE II BOMEX Cruise
July 21, 1969

Hour GMT	Position Lat.	Long.	$O_3(R)$ pphm	$O_x(M_1)$ pphm	$O_x(M_2)$ pphm	$O_3(R)/O_x(M_1)$ Ratio(%)	$O_3(R)/O_x(M_2)$ Ratio(%)	CH_4 ppm	CO ppm	Remarks
0000	32°05'N	78°51'W	0.9	M	0.8	M	113			
0100	32°20'	78°42'	0.8	M	0.8	M	100			
0200	32°33'	78°37'	0.7	M	0.9	M	78			
0300	32°45'	78°32'	0.6	M	1.0	M	60			
0400	32°59'	78°28'	1.0	1.2	1.0	83	100	1.36	.22	
0500	33°12'	78°23'	0.6	1.1	1.0	55	60			
0600	33°25'	78°18'	0.8	1.0	1.1	80	73			
0700	33°36'	78°11'	0.7	0.9	1.1	78	64			
0800	33°49'	78°06'	0.7	1.1	1.1	64	64			
0900	33°49'	78°06'	0.7	1.1	1.0	64	70			
1000	33°49'	78°06'	0.9	1.1	1.0	82	90	M	M	
1100	33°49'	78°06'	0.7	1.0	1.0	70	70			
1200	33°49'	78°06'	M	M	M	M	M			
1300	33°49'	78°06'	M	M	M	M	M			
1400	33°49'	78°06'	0.4	M	M	M	M			
1500	33°49'	78°06'	0.5	M	M	M	M			
1600	33°49'	78°06'	M	M	M	M	M	M	M	
1700	33°49'	78°06'	M	M	M	M	M			
1800	33°49'	78°06'	M	M	M	M	M			
1900	33°49'	78°06'	M	M	M	M	M			
2000	33°49'	78°06'	M	M	M	M	M			
2100	33°49'	78°06'	M	M	M	M	M			
2200	33°49'	78°06'	M	M	M	M	M	M	M	
2300	33°49'	78°06'	M	M	M	M	M			